GPU Nuclear Corporation

Update of Alternate Cooling Water System Study

For

Oyster Creek Nuclear Generating Station

Volume 1
Technical and Economic Evaluation

August 1992

EBASCO

An ENSERCH® Engineering and Construction Company

GPU NUCLEAR CORPORATION
OYSTER CREEK NUCLEAR GENERATING STATION
UPDATE OF ALTERNATE COOLING WATER SYSTEM STUDY

VOLUME 1
TECHNICAL AND ECONOMIC EVALUATION

EBASCO SERVICES INCORPORATED

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1.0 SUMMARY

1.1 PURPOSE

The Oyster Creek Nuclear Generating Station (OCNGS) utilizes an open cycle cooling system in which the main condenser cooling water is supplied via a man-made intake canal from Forked River and then discharged to Oyster Creek. Although the cooling system consistently meets pertinent environmental regulatory limits, there have been environmental impacts. To determine the benefits and costs of implementing a cooling system alternative to the existing condenser cooling system, Ebasco evaluated engineering, cost, licensing, and environmental factors, of sixteen (16) open cycle and closed cycle cooling water systems. The study, "Alternative Cooling Water System Study", November 1977 (Reference 1), identified four "preferred" cooling systems: natural draft cooling tower, round mechanical draft cooling tower, fan assisted natural draft cooling tower and discharge canal to bay. Of these four, the study concluded that the natural draft cooling tower system is the optimum.

The purpose of this study is to update the technical, economic and environmental findings of the original study with respect to the two (2) preferred cooling water alternatives, i.e. natural draft cooling tower (NDCT) and round mechanical draft cooling tower (RMDCT).

The technical and economic evaluations are presented in Volume 1. Environmental evaluations are presented separately in Volume 2.

1.2 SCOPE

This study is performed in accord with the scope of work described in Ebasco's proposal "Update of Alternate Cooling Water System Study for Oyster Creek Generating Station", December 1991.

The two best closed cooling alternatives from the original study, the natural draft cooling tower (NDCT) and round mechanical draft cooling tower systems (RMDCT), are evaluated. Detailed information contained in the original study was reviewed and the information updated for those technical, cost and environmental aspects that have been superseded based on current plant conditions, cooling system technology, environmental and regulatory criteria. For example, cooling system investment and operating costs are updated for today's equipment costs, GPUN's economic factors, remaining plant operating life, and forecasted replacement energy costs.

In this volume technical and economic aspects of the NDCT and RMDCT alternatives are evaluated in the following tasks:

1) Review the original study and confirm or update the criteria and assumptions consistent with current site characteristics, plant design, performance, environmental and regulatory requirements;
2) Update the technical design, including preliminary design, performance and cost information from a cooling tower vendor;
3) Update the Ebasco computer program "Economic Selection of Steam Condensing System" (CSIZE2011), including:
   - site, plant and cooling system design features and performance
   - major equipment prices, e.g. cooling towers, pumps
   - balance of plant material and installation costs
   - GPUN economic factors

1.3 RESULTS

Two arrangements of evaporative cooling towers are evaluated: a single concrete, hyperbolic natural draft cooling tower (NDCT); and two (2) 50% capacity round mechanical draft cooling towers. A schematic flow diagram and layout drawing are given for the NDCT in Exhibits 5 and 6, respectively, and for the RMDCT in Exhibits 12 and 13, respectively. Condensing system and plant overall performance, investment costs, and comparable annual costs including demand and energy charges for differential generation with respect to the existing system are given in Exhibits 29 and 30 for the NDCT and RMDCT, respectively.

NDCT and RMDCT design and performance parameters are:

	NDCT	RMDCT
No. Towers	1	2
Flow rate, gpm	416,200	373,100
Range, F	20.2	22.6
Approach Temp, F	12	10
Cold Water Temp, F	86	84
Hot Water Temp, F	106.2	106.6
Base Diameter,ft	409	210
Height, ft	600	62
Pumping head, ft	42	38
Evaporation Loss, %	1.8	2.06
Drift Loss, %	0.001	0.001
No. Fans / Motor HP	NA	12 per tower / 200

The proposed cooling tower(s) would be located on the north side of the plant. Cold water would be pumped by circulating water pumps through 12 ft (NDCT) or 11 ft (RMDCT) diameter reinforced concrete conduits to and from the existing circulating water intake and discharge tunnels. The conduits would be buried.

Circulating water system total head requirement is approximately 74.4 ft for the NDCT and 68.6 ft for the RMDCT. To satisfy the intake tunnel design pressure of 41 feet, the total pumping head is divided between four (4) 800 hp vertical type circulating water pumps located at the cooling tower and (4) 1500 hp horizontal type booster circulating water pumps located in the hot water return piping.

Circulating water system electric power requirements for pump, fan and miscellaneous equipment motors are provided using existing 4160 V 1A, 1B and dilution pump switchgear, new 4160 V switchgear and new 480 V power centers.

Intake water would be used for cooling tower makeup and would require pretreatment in a brine clarifier/reactivator to reduce the calcium hardness. Makeup flow would be approximately 15,000 gpm based on operating the circulating water at 2 to 2.5 cycles of concentration. Cooling tower blowdown is calculated to be a volume of about 7,500 gpm and would be piped to the discharge canal. Clarifier sludge would be dewatered and compacted for offsite disposal.

Compared to the existing cooling system, the use of cooling towers will reduce plant net capacity and generation due to higher turbine exhaust pressure and higher auxiliary power demands. At design temperature conditions net capacity would decrease by about 15 MW for the NDCT and 19 MW for the RMDCT.

Parameter	Existing	NDCT	Round MDCT
Design WB Temp, F	NA	74	74
Design CW Temp, F	82	86	84
Condenser Pressure, in Hga	2.66	3.18	3.24
TG Output, MW	616.8	605.8	604.5
BOP Aux. Pwr, MW	17.5	17.5	17.5
CWS Aux. Pwr, MW	3.2	7.6	10.3
Plant Net Output, MW	596.1	580.7	576.7
Differential, MW	Base	-15.4	-19.4
Net Generation, MWH/yr	4,039,400	3,939,100	3,923,200
Differential, MWH/yr	Base	-100,300	-116,200

where TG equals Turbine Generator, BOP equals Balance of Plant and CWS equals Circulating Water System.

NDCT and RMDCT total investment costs, comparable annual costs including demand and energy charges for differential net generation compared to the existing system, and comparable capitalized costs (based on a 23.42% levelized fixed charge rate) are:

Parameter (1995 $)	NDCT	Round MDCT
Total Investment Cost, $	98,550,000	91,100,000
Differential, $	Base	-7,450,000
Comparable Levelized Cost, $/yr	33,200,000	33,500,000
Differential, $/yr	Base	+300,000
Comparable Capitalized Cost, $	141,800,000	143,000,000
Differential, $	Base	1,200,000

Investment cost includes all costs to erect cooling tower and basin, pumps, piping, intake and pump house structures, electrical, water treatment, etc. Comparable levelized cost includes investment fixed charge, O&M, plus adjustment (energy/demand charge) for differential net generation compared to the existing condensing system. This cost is calculated on an annual basis for the 15 years from 1995 to 2009 when the plant's operating license expires. Comparable capitalized costs = total comparable capitalized cost/levelized fixed charge rate.

1.4 CONCLUSIONS

Incorporation of either cooling tower alternative appears technically feasible subject to more detailed engineering and cost studies of the cooling tower, circulating water pipe, water treatment equipment arrangements, electric power supply, circulating water pump total head and system operational requirements with respect to limitations of the existing cooling system (i.e. intake tunnel design pressure).

The economic impact of either the NDCT or RMDCT is high due to significant investment cost and reduced net generation. Total comparable costs are essentially equal.

2.0 DISCUSSION

2.1 METHODOLOGY

The original study evaluated and selected the natural draft and round mechanical draft cooling tower systems as "preferred" based on cost and environmental considerations. For this study, these cooling system alternatives are evaluated technically, economically and environmentally based on today's criteria.

Compared to the existing cooling system, incorporation of an alternative cooling system utilizing cooling towers will reduce plant net output. Cooling water temperature is warmer, resulting in higher condenser pressure and reduced generator output. Station auxiliary power consumption increases from greater circulating water pump power and cooling tower fans.

Each cooling system is technically and economically evaluated to identify the optimum design using Ebasco's computer program "Economic Selection of Steam Condensing System" which was used in the original study. Program description is given in Appendix A.

Cooling system alternatives are evaluated in two levels of detail. In the first level of detail a cooling system economic optimization study is performed on a comparative basis to identify the technically acceptable and economically preferred NDCT and RMDCT system process specifications. The evaluation is based on cooling tower design, performance and cost parameters provided by a cooling tower vendor for alternative cold water and range temperature conditions. In the second level of detail, the cooling tower vendor provides refined design, performance, and cost data for the specific optimized cooling tower specifications. This data is used to perform more detailed engineering, economic and environmental evaluations.

2.2 COOLING SYSTEM DESCRIPTION

2.2.1 EXISTING COOLING SYSTEM

Exhibit 1 shows the Oyster Creek NGS site bounded by Barnegat Bay to the east, Forked River to the north and Oyster Creek on the south. The condenser cooling system, Exhibit 2, is an open-loop cooling system whereby the condenser heat load is ultimately discharged to Barnegat Bay via intake and discharge canals connecting Forked River and Oyster Creek, respectively. Four circulating water pumps convey the mixture of salt and fresh water from Barnegat Bay and Forked River through the intake canal and the condenser to the discharge canal. Circulating water pumps are located in the intake canal. A dam separates the intake and discharge canals.

The turbine exhaust steam condenser consists of three single-pass, single pressure shells manufactured by Worthington. The original tube material was replaced with titanium in the early 1970s. Condenser design parameters from References 2a and 2b are:

No. Shells	3
Surface Area per Shell	141,000 sq ft
Cooling water flow per Shell	150,000 gpm
No. Tubes per Shell	14,562
Tube Length	42.5 ft
Tube Material	Titanium
Tube Diameter x Wall Thick.	7/8 in x 22 BWG
Tube Cleanliness Factor	95%

The condenser is supplied by four (4) 115,000 gpm, 28.5 ft TDH, 1000 HP vertical type circulating water pumps located at the intake canal pump house. The intake canal also supplies three (3) 800 hp dilution pumps that may be used to regulate discharge canal water temperature.

Cooling water is conveyed from the intake canal through the condenser to the discharge canal via 10.5 ft x 10.5 ft concrete intake and discharge tunnels. Tunnel, condenser pipe and valve arrangement facilitates condenser tube backwashing.

The circulating water system intake tunnel has a design pressure of 41 ft which restricts the maximum allowable circulating water pump discharge pressure, the number of pumps and condenser water boxes in service, and condenser backwash procedures (Reference 2c).

The performance of the existing condensing system, turbine generator output and plant net generation is calculated in Exhibit 3. At the average annual cold water temperature, the existing condensing system produces nominally 640 MW gross. In order to allow for comparability with the cooling tower alternatives, the existing condensing system was evaluated at an equivalent ambient temperature. This results in an 84 F cold water temperature.

<u>Existing Condensing System Parameters</u>	
Cold Water Temp, F	84
Condenser Pressure, in Hga	2.66
TG Output, MW	616.8
BOP Aux. Pwr, MW	17.5
CWS Aux. Pwr, MW	3.2
Plant Net Output, MW	596.1
Net Generation, MWH/yr	4,039,400

2.2.2 NATURAL DRAFT COOLING TOWER SYSTEM

NDCT arrangement, system flow diagram and site layout are given in Exhibits 4, 5 and 6, respectively. A single cooling tower can handle the total condenser and auxiliary service water heat load and flow requirement.

Major equipment includes:

- o hyperbolic counterflow natural draft cooling tower and basin
- o horizontal and vertical circulating water pumps (8 total)
- o circulating water concrete conduit
- o circulating water pump house
- o electric switchgear, cables
- o makeup water pumps, piping
- o makeup water treatment system
- o water treatment sludge disposal system
- o blowdown water piping
- o condenser tube cleaning system

Cooling Tower

The natural draft or hyperbolic counter flow cooling tower relies on the structure's "chimney" effect to induce ambient air to flow upward through the tower "fill". Hot circulating water flows over the fill and is cooled by the air flow via evaporative and convective cooling.

One NDCT is required. Cooling tower design, performance and budget cost data for comparative analyses is shown in Exhibit 22. Data are provided for towers with approach temperature from 12 to 16 F and range temperatures from 16 to 24 F. The economically optimized tower is approximately 600 ft tall and has a base diameter of 409 ft.

Circulating Water Conduit

The cooling tower is assumed to be located at the north side of the plant. Reinforced concrete conduit convey the circulating water between the cooling tower and existing intake and discharge tunnels.

The design pressure of the intake tunnel is 41 ft. This limits the allowable circulating water pump discharge pressure. For closed cooling alternatives utilizing cooling towers that have a high total head (for the NDCT system approximately 74 ft), the overall system pumping head requirement is minimized by the use of large diameter conduits. Furthermore, the intake tunnel pressure limitation requires that the total pumping head be shared between two sets of circulating water pumps. One set of four (4) CW pumps are located in the cooling tower basin and a set of four (4) booster CW pumps are located in the return piping to the cooling tower.

The TDH of each pump must be specified such that the following criteria are met:

a. cumulative pump head equals the sum of pipe friction, condenser friction and cooling tower pumping head;
b. the intake tunnel 41 ft pressure limit is not exceeded during all operating modes;
c. main and booster circulating pump NPSH requirements are met;
d. maximum siphon head is not exceeded (typically 25-26 ft).

A CWS hydraulic grade line given in Exhibit 7. For the optimized case, the circulating water flow rate is about 416,000 gpm and the reinforced concrete conduit diameter is 12 ft. Total conduit length is about 2,900 ft. Vertical circulating water pump head is 26.4 ft and the horizontal booster circulating water pump head is 48 ft. Intake tunnel pressure is 39 ft and condenser siphon head is about 19.5 ft.

Electric Power Supply

Cooling system electric power requirements for the circulating water pumps, makeup water pumps, water treatment equipment, valve motors and miscellaneous equipment will be supplied from existing

4160V buses 1A, 1B, and dilution plant switchgear, new 4160V switchgear, new 480V power centers and motor control centers.

A conceptual one line diagram of the major electrical components of the NDCT power supply is shown in Exhibit 8. The existing 4160 V switchgear buses 1A and 1B will be used to supply the four (4) new 800 hp circulating water pumps. The existing dilution pump 4160 V switchgear would feed two (2) 1500 hp booster pumps, an 400 hp makeup water pump and a new 480 V power center #1. A feed is provided from startup transformer SB to new 4160 V switchgear to supply the other two (2) booster pumps, makeup water pump and new 480 V power center #2.

Makeup Water Treatment

Intake canal water is used for cooling tower make-up. Intake water analysis from the original study is analyzed in Exhibit 9. Calcium hardness must be reduced by lime softening. The reduced hardness will enable the cooling tower to operate between 2 to 2.5 cycles of concentration. At the design wet bulb temperature the makeup water rate is approximately 15,000 gpm. About 7,500 gpm is lost to evaporation and 7,500 gpm is discharged to the discharge canal. Makeup water is supplied by two (2) 50% capacity 400 HP pumps which would be located in the existing intake canal CW pump house.

Water treatment schematic diagram is shown in Exhibit 10. Raw water is pumped to the brine clarifier/reactor where chemicals are added to enhance the removal of calcium hardness. The treated effluent is discharged to the cooling tower. The excess sludge is collected and discharged to a thickener where it is further concentrated before it is sent to a filter press to be dewatered to a truckable solid for offsite disposal.

2.2.3 ROUND MECHANICAL DRAFT COOLING TOWER SYSTEM

Cooling tower arrangement, system flow diagram and layout for the Round Mechanical Draft Cooling Tower (RMDCT) system are given in Exhibits 11, 12 and 13. Major equipment is the same as for the NDCT except that two (2) RMDCT are required, and 2 additional new 480 V power centers are required to supply the cooling tower fans.

Cooling Tower

The round mechanical draft cooling tower utilizes fans to induce the air to flow through the cooling tower. Cooling tower design, performance and cost data for comparative purposes are given in Exhibit 23. The two (2) cooling towers are assumed to be located north of the plant. Basin water flows to a common intake pump structure.

Circulating Water Conduit

Conduit diameter would be 11 ft based on the optimized case flow of 373,000 gpm. Hydraulic gradient is shown in Exhibit 14. Circulating water system total head is 68 ft, which is divided between the main circulating water pump (26.1 ft) and the booster pump (42.5 ft). Intake tunnel pressure is 39 ft and the condenser siphon head is 16.8 ft.

Electric Power Supply

A conceptual one line diagram of the major components of the RMDCT power supply system is shown as Exhibit 15. Power supply from existing and new 4160 V switchgear for the four CWPs, four booster CWPs, two makeup water pumps and two 480 V power centers are the same as for the natural draft cooling tower. Two additional 480 V power centers are provided for the cooling tower fans.

Makeup Water Treatment

The system is the same as for the NDCT. Circulating water analysis is shown in Exhibit 16. At the design wet bulb temperature the makeup water flow is 15,400 gpm based on an evaporation loss of 7,700 gpm and blowdown flow of 7,700 gpm.

2.3 COOLING SYSTEM OPTIMIZATION INPUT DATA

2.3.1 COOLING SYSTEM PARAMETER ALTERNATIVES

Condenser tube water velocity

The existing condenser design flow rate is 450,000 gpm and the condenser tube water velocity is 6.3 ft/s. The condenser tube velocity affects the cooling water temperature rise, flow rate, condenser pressure and generator power output. Higher tube velocity results in higher generator output due to better condenser heat transfer performance and reduced turbine exhaust pressure. But the higher flow rate increases the cooling tower cost, pump head and pump power. Lower tube velocity results in lower generator output, but also lower cooling system cost, pumping head and power.

Titanium condenser tubes may be expected to operate satisfactorily over a wide velocity range. For optimization of new cooling water systems the economically preferred titanium tube design velocity is typically between 6 to 12 ft/s. However for this study, in which the existing condenser and circulating water conduits are fixed designs, the water velocity was evaluated over the range of 5.0 ft/s to 7.2 ft/s based on the following considerations:

- o low velocity (high cooling water temperature range) to reduce cooling tower, pump and piping costs, pumping head, and satisfy the intake tunnel design pressure limitation; minimum velocity for the Amertapp tube cleaning system (for study purposes only) is 5 ft/s;

- o high velocity (low cooling water temperature range) to increase condenser performance and generator output.

Resulting condenser flow rate and water temperature rise versus tube water velocity, based on the full load condenser duty of 4110 million Btu/hr (at 1860 MWt), 3 shells and 14,562 tubes/shell (7/8 inch diameter, 22 BWG) are:

Condenser Tube Water Velocity, ft/s	Condenser Flow, gpm	Temp. Rise,F
5.0	359,000	23.6
6.27	450,000 (design)	18.8
7.2	517,000	16.4

where temperature rise = Heat Duty/(Gpm x 500 x Cp x SG) ; assuming water equal to 1.5 normal sea water concentration or 50,000 ppm, Cp = 0.94 and SG = 64.4/62.4 = 1.03.

Cooling Tower Flow Rate

Cooling tower flow equals the condenser flow plus 10,000 gpm auxiliary service cooling water (flow to the turbine building closed cooling water heat exchanger).

Cooling Tower Range Temperature

Cooling tower water range temperature (i.e. hot water inlet temperature minus the cold water outlet temperature) is governed by the condenser and auxiliary service water system heat loads and flow rates. For this study, the cooling tower range temperature is assumed equal to the condenser temperature rise.

Cooling Tower Approach Temperature

Cooling tower cold water temperature performance is governed by the "approach temperature" to the ambient air wet bulb temperature. The ambient wet bulb temperature is the same as in the original study, 74 F. This equals the mean coincident wet bulb temperature corresponding to the 2.5% summer (June, July, August, September) frequency dry bulb temperature (89F) for Atlantic City as given in Reference 7.

From Ebasco's experience with numerous cooling tower economic evaluations, the economically preferred cooling tower will generally have a high range temperature (to reduce the flow rate and capital cost) and low approach temperature (to lower the condenser pressure and increase generator output). For this study, the range temperatures described above and the following cooling tower approach temperatures are considered:

NDCT:	12; 14; 16 F
RMDCT:	8; 10; 12 F

2.3.2 PROJECT FINANCIAL CRITERIA

A. Material and installation cost escalation: 4.1 %/yr (reference 3c).
The escalation period is assumed to be three years based on system operation starting in 1995.

B. Sales/Use Taxes: 5% of direct material cost.

C. <u>Indirect Construction Cost</u>: 15 % of total direct escalated cost.

Indirect Construction Cost has been estimated as a percentage of total direct escalated costs based upon Ebasco's in house data.

Indirect Construction Costs include architectural/engineering and related services such as design, engineering, purchasing, expediting, inspection, traffic, start-up services, construction management, locally hired non-manual employees (secretary, bookkeeper, surveyor), cars, pick-up trucks, site trailers and office expenses to support a construction management team at the site.

D. <u>Contingencies</u>: 14% of total direct and indirect escalated cost.

The contingency allowance has been estimated as a percentage of total direct and indirect escalated costs based upon Ebasco's experience. It covers the following items: conceptual quantities for earthwork, concrete, piping, and electrical; lack of firm pricing for major equipment; and the current phase of design (conceptual) for this study.

E. <u>Interest During Construction</u>: 10%/yr (reference 3a).

F. <u>Utility's Expenses</u>: 6% of total direct costs.

This is to cover GPUN's administrative, engineering and supervisory costs and taxes during construction, and is the same as used in the original study.

G. <u>Levelized Maintenance Cost</u>: natural draft cooling tower, 2% of total investment; round mechanical draft, 3% of total investment cost plus $3,800 per fan.

H. Levelized Fixed Charge Rate: 23.42 % of the capital cost. This is the "carrying charge" need to cover expenses for return on weighted capital, book depreciation, income tax liability, property taxes and insurance. It is equal to the sum of the capital recovery factor (calculated at the rate of return, below) plus 9.7% from the original study for taxes and insurance. The economic evaluation period is 15 years from 1995 to 2009 when the plant's operating license expires.

I. Rate of Return: 10.78% (reference 3b). This is used to calculate the levelized replacement energy cost (see item L).

	Capitalization Ratio Target	Average Cost	Weight Return
Long-Term Debt	45%	9.5%	4.28%
Preferred Stock	11%	8.7%	0.96%
Common Stock Equity	44%	12.6%	5.54%
	100%		10.78%

J. Incremental Net Capability Charge: the demand charge is included in the replacement energy cost (item 1).

K. Nuclear Fuel Cost: this cost is not required since the fuel input is constant for all cases.

L. Levelized Replacement Energy Cost: $77.71 / Mwh. This is based on GPUN data (Reference 2d) for energy and demand charges, and is derived in Exhibit 17.

M. Levelized Makeup Water: $19.23 per million gallons; chemical treatment, $50 per million gallons. Water cost is based on the makeup pump replacement power cost. Chemical treatment is escalated from the original study cost of treatment (e.g. chlorine, etc.).

N. <u>Land Cost</u>: No cost. Both alternatives examined would locate the cooling tower(s) on land currently owned by GPUN. Additional land required to meet the noise regulations as discussed in Volume 2, Section 7.2.3 - Noise Impacts, have been excluded from this study.

2.3.3 INTAKE CANAL WATER CONDITIONS

Average monthly and seasonal cooling water temperatures used to determine the performance of the existing condenser system for comparison against cooling tower alternatives are given in Exhibit 18. Seasonal temperatures are:

Ambient Condition	CW Temperature, F
Condenser design	82 F
Average summer	76 F
Average spring/fall	55 F
Average winter	36 F

2.3.4 AMBIENT AIR TEMPERATURE CONDITIONS

Average monthly ambient dew point and dry bulb temperatures from Atlantic City, NJ, 1/81 to 12/85 were used to determine the average monthly and seasonal wet bulb temperature conditions. See Exhibit 19.

Turbine Cycle Heat Balance

The turbine generator is a General Electric TC6F-38 LSB unit with Valves Wide Open (105% flow) gross output and heat rate of 670,005 Kw and 9,797 Btu/Kwh at 1.0 in HgA exhaust pressure. Reactor thermal output is 1930 MW. Throttle steam conditions are 6,834,590 lb/hr at 965 psia and 1191.2 Btu/lb. Condenser heat duty is 4,360 MMBtu/hr. Exhibits 20a and 20b illustrate the turbine cycle heat balances for the Valves Wide Open case and the 100% load case, respectively.

Generator output may be calculated for various exhaust pressures using exhaust pressure heat rate correction factors shown in Exhibit 21 and the following equation:

Change in Kw = (-% Change in Heat Rate)*100/(100-% Change in Heat Rate)

Plant Operation

The plant is assumed for this study to operate (base loaded) equivalent to a 75% capacity factor. For study purposes, the turbine generator is assumed to operate at 100% guaranteed load gross output and heat rate of 640,757 Kw and 9,821 Btu/Kwh, respectively, at 1.0 in HgA exhaust pressure, for 0.75 * 8,760 hr/yr = 6,570 hr/yr. Reactor thermal output is 1860 MW. Throttle steam conditions are 6,509,130 lb/hr at 965 psia and 1191.2 Btu/lb. Condenser heat duty is 4,110 MM Btu/hr.

The turbine cycle heat balance for this case is shown in Exhibit 20b.

2.3.6 CIRCULATING WATER SYSTEM LAYOUT

Piping layout is shown in Exhibits 6 and 13 for the NDCT and MDCT, respectively. The cooling tower is located on the north side of the plant for both layouts. New piping connects the cooling tower to the existing circulating water conduits. The new conduits are buried. Since ground water is close to the surface (less than 10 ft), pipe installation is assumed to require sheet piling.

Circulating water system TDH is calculated based on the following pipe arrangement:

	No. Pipes	Flow, %	Avg Length, ft	K-Factor
Existing System + New CT Intake				
Main	1	100	2,100	4.5
Branch	1	100	500	3
Branch	6	16.7	150	3
New Conduits				
Main - Supply	1	100	1345	.7
Main - Rtn	1	100	1540	1
Branch	4	25	38	1.5

2.3.7 COOLING TOWER PARAMETERS

Preliminary NDCT and RMDCT design, performance and cost information was received from Marley Cooling Tower Company for the purpose of comparative evaluations. Cooling tower size, pump head, fan power, evaporation loss and budget price are given for NDCT and RMDCT alternatives in Exhibits 22 and 23, respectively.

2.3.8 PRICING INFORMATION

A. Pricing Data Stored On Computer

Vertical circulating water pump and motor budgetary costs were obtained from Ingersoll Rand Pump Division (reference 5).

Pump Type	Vertical, wet pit for salt water
Pump Model	58 APMA
Capacity, gpm	110,000
Total Head, ft	42
Efficiency, %	87
Motor HP/Volt/rpm	15,000/4000/400
Pump Price, $	300,000
Motor Price, $	225,000

The above pump and motor prices were used to determine a "discount factor" to adjust vertical pump, horizontal pump and motor price data contained in the computer program. The discount factor was derived to be equivalent to the combined cost of a "composite" vertical circulating water pump consisting of one vertical CW pump and one horizontal booster CW pump. This was necessary for the computer program to determine a cost equivalent to two circulating water pumps arranged in series.

Discount factors used for the "composite" vertical pump and motor were:
Vertical pump: -4.01 on 1968 price list (or a 5.01 multiplier on the computer price);
Motors: -1.36 on 1975 price list (or 2.36 multiplier)

B. <u>Pricing Data Input Directly to Computer</u>

Current pricing data was quoted by vendors or estimated by Ebasco for major site development, circulating water intake structures, conduits, cooling towers, electrical equipment, power cables, local clearing, etc. Pricing data is listed in Exhibit 24. Land cost for noise abatement was excluded.

2.4 COOLING SYSTEM ECONOMIC OPTIMIZATION RESULTS

The Ebasco computer program "Economic Selection of Steam Condensing System" was used to evaluate the design, performance, investment cost and comparable annual costs for NDCT and RMDCT. Program description is given in Appendix A.

The computer analysis was performed for the following alternatives:

<u>Condenser Tube Water Velocity, (ft/s)</u>

5.0 - 7.2 ft/s in steps of 0.2 ft/s

<u>Cooling Water Approach Temperature (74 F wet bulb temperature)</u>

NDCT: 12; 14; 16 F

RMDCT: 8; 10; 12 F

Natural draft and mechanical draft cooling tower technical, investment cost and annual cost computer results summary for each approach temperature are given in Appendix B. Investment cost includes all costs to erect cooling tower and basin, pumps, piping, intake and pump house structures, electrical, water treatment, etc. Land costs to meet noise regulations have been excluded from this study. Annual cost (levelized) includes investment fixed charge, O&M, plus adjustment (energy/demand charge) for differential net generation compared to the existing condensing system. Capitalized costs = total annual cost/levelized fixed charge rate (23.42%).

2.4.1 NATURAL DRAFT COOLING TOWER SYSTEM

Total investment cost, comparable annual cost and capitalized annual cost, are given in Exhibit 25. Investment and capitalized costs are also graphically shown in Exhibit 26.

NDCT investment costs range from $85 to $116 million, depending on the tower type, cold water approach temperature, and tube water velocity (which sets the temperature range and flow rate). Capital cost increases as the cold water temperature decreases and the tube water velocity (or flow rate) increases.

Comparable capitalized costs varies from $143 million to $167 million.

2.4.2 ROUND MECHANICAL DRAFT COOLING TOWER SYSTEM

Investment, levelized comparable annual and capitalized costs are presented in tabular and curve form in Exhibits 27 and 28.

Investment cost ranges from $86 to $118 million. Although these costs are nearly the same as for the NDCT, RMDCT specifications are more difficult since cold water approach temperatures are 4 F cooler (e.g 8 to 12 F vs 12 to 14 F for the NDCT).

Comparable capitalized cost ranges from $144 to $162 million which is from $5 million lower to $1 higher than the NDCT.

2.4.3 ECONOMICALLY PREFERRED COOLING TOWER SPECIFICATION

One the basis of low comparable cost, the economically preferred NDCT and RMDCT towers have the following specifications:

	NDCT	RMDCT
Cold approach temperature, F	12	10
Condenser tube velocity, ft/s	5.8	5.2
Condenser range temp, F	20.2	22.6
Cooling Tower flow, gpm	416,200	373,100

Design, performance and cost data for these specific selections are given in the next section.

2.5 COOLING SYSTEM DESIGN, PERFORMANCE AND COST PARAMETERS

Cooling tower economically optimized specifications were evaluated by Marley Cooling Tower Company who provided detailed design, performance and cost information (References 6b and 6c). This information was analyzed to estimate condensing system performance, investment and evaluated costs parameters.

2.5.1 Natural Draft Cooling Tower System

Computer printout of NDCT condensing system parameters is given in Exhibit 29. Hydraulic gradient and circulating water analyses are given in Exhibits 7 and 9.

Major technical, performance and cost data are summarized below:

A. Natural Draft Cooling Tower

Design Conditions:

Approach to Twb = 74 F	12
Cooling Range,F	20.2
Circulating Water Flow, gpm	416,200
CW Temperature, F	86

Description:

Cooling Tower Type	Counterflow, concrete
No. Towers	1
Diameter, ft	409
Height, ft	600

Performance:

Pumping Head, ft	42
L/G Ratio	1.74
Evaporation Loss, %	1.8
Max. Drift Loss, %	0.001
Sound Power Level @ 50 ft	121 x 10^-12 Re

Sound Pressure Level:

Hz	31.5	63	125	250	500	1000	2000	4000	8000
Db	54	56	56	57	66	67	67	70	69

Budget Price (1992 $): $22,650,000

B. Circulating Water Pumps

Type	Vertical
Number	4
Capacity, gpm	104,100
Total Head, ft	28.9
Motor Rating, hp	800

C. Booster Circulating Water Pumps

Type	Horizontal
Number	4
Capacity, gpm	104,100
Total Head, ft	48
Motor Rating, hp	1500

D. Circulating Water Piping

Type	Reinforced Concrete
Diameter	144 in
Pipe Velocity	8.2 ft/s

E. Station Performance

Design CW Temp, F	86
Condenser Pressure, in Hga	3.18
TG Output, MW	605.8
BOP Aux. Pwr, MW	17.5
CWS Aux. Pwr, MW	7.6
Plant Net Output, MW	580.7
*Differential, MW	-15.4
Net Generation, MWH/yr	3,939,100
*Differential, MWH/yr	-100,300

*Compared to existing cooling system (Exhibit 3)

F. Cooling System Investment and Comparable Costs (1995 $)

Total Investment Cost, $	98,550,000
Comparable Levelized Cost, $/yr	33,200,000
Comparable Capitalized Cost, $	141,800,000

2.5.2 Round Mechanical Draft Cooling Tower System

Computer printout of RMDCT condensing system parameters is given in Exhibit 30. Hydraulic gradient and circulating water analyses are given in Exhibits 14 and 16.

Major technical, performance and cost data are summarized below:

A. Round Mechanical Draft Cooling Tower

Design Conditions:

Approach to Twb = 74 F	12
Cooling Range, F	22.6
Circulating Water Flow, gpm	373,100
CW Temperature, F	84

Description:

Cooling Tower Type	Counterflow, concrete
No. Towers	2
Diameter, ft	210
Height, ft	62
Fan Deck Height, ft	48
No. Fans	12
No. Blades	8
Fan Diameter, ft	28
Full/Half Speed	
Rpm	137/68.5
BHP	200/25
Blade Pass. Freq, cpm	1096/548

Performance:

Pumping Head, ft	38
L/G Ratio	1.404
Evaporation Loss, %	2.06
Max. Drift Loss, %	0.001
Sound Power Level @ 50 ft	120 x 10^-12 Re

Sound Pressure Level @ Full and Half Speed, Db:

Hz	31.5	63	125	250	500	1000	2000	4000	8000
100%	81	82	78	72	70	70	68	70	70
50%	73	74	66	70	58	63	65	72	72

Budget Price (1992 $): $17,410,000

B. Circulating Water Pumps

Type	Vertical
Number	4
Capacity, gpm	93,350
Total Head, ft	26.1
Motor Rating, hp	800

C. Booster Circulating Water Pumps

Type	Horizontal
Number	4
Capacity, gpm	93,350
Total Head, ft	42.5
Motor Rating, hp	1250

D. Circulating Water Piping

Type	Reinforced Concrete
Diameter	132 in
Pipe Velocity	8.8 ft/s

E. Station Performance

Design CW Temp, F	84
Condenser Pressure, in Hga	3.24
TG Output, MW	64.5
BOP Aux. Pwr, MW	17.5
CWS Aux. Pwr, MW	10.3
Plant Net Output, MW	576.7
*Differential, MW	-19.4
Net Generation, MWH/yr	3,923,200
*Differential, MWH/yr	-116,200

*Compared to existing cooling system (Exhibit 3)

F. Investment and Comparable Costs (1995 $)

Total Investment Cost, $	91,100,000
Comparable Levelized Cost, $/yr	33,500,000
Comparable Capitalized Cost, $	143,000,000

The seperate component material and installation differential costs from Exhibit 29 (NDCT) and Exhibit 30 (RMDCT) are shown in Exhibit 31.

LIST OF REFERENCES

LIST OF REFERENCES

1. Jersey Central Power and Light Oyster Creek NGS "Alternative Cooling Water System Study", Ebasco Services Inc., November 1977: Volume I Executive Summary; Volume II Study Text; Volume III Discussion of Alternative Cooling Water Systems; Volume IV Discussion of Preferred Cooling Water Systems.

2. Information from GPUN, T. Ruggiero (GPUN) to F. Kuo (ESI), 4/7/92:

   a. Expected Condenser Performance Curves (for titanium retubing), Worthington, Doc. No. E-147920, 10/17/75

   b. Surface Condenser Engineering Data, Worthington, Doc. No. 1-604949-951, undated

   c. GPUN System Design Basis Document Circulating Water System, Doc. No. SDBD-OC-535, Rev.0: Section 4.2 Process and/or Operational Requirements, pp 56-65; Section 4.3 Configuration and Essential Features, pp 65-70; Section 4.5 Structural Requirements, pp 81-86

   d. Replacement Power Costs ($/MWeH), 1991 to 2009, dated 5/1/91 (energy value and PJM capacity charge rate)

   e. General Electric Turbine Generator TC6F-38 LSB, 1800 rpm 640,700 Kw:

      1) Heat Balance, GE Dwg. No. 332HB796, 5/4/64 (100% load output 640,757 kw at 6,509,130 pph throttle steam, 1860 Mwt reactor heat)

      2) Exhaust Pressure Correction Factors, GE Dwg. No. 452HB158, 10/28/76

3. GPUN Information, T. Ruggiero (GPUN) to F. Kuo (ESI), 5/6/92:

   a. Interest during construction, 10%;
   b. Weighted return requirement, 10.78%;
   c. Long term inflation rate, 4.1%
   d. 1976-1980 Annual and Monthly Mean Water Temperature (Table 2 Duncans Multiple Range Test)

4. Oyster Creek NGS Drawings:

   a. Flow Diagram Circulating, HP Screen Wash, Service & Emergency Service Water Systems, Dwg. No. BR2005, Rev. 6

   b. Main One Line Diagram, Dwg. 3001, Rev. 9

c. Auxiliary One Line Diagram, Dwg. BR3002, Rev. 14

d. General Arrangement Turbine Building As Built, Dwg 3E-151-02-001, -002, -007, -009, Rev. 0 (all)

e. Site Plan, Dwg. 19702, Rev. 11

f. Site Plan - Topographic Survey, Dwg 19701: Sheet 5, Rev. 2; Sheet 6, Rev. 6; Sheet 7, Rev. 6; Sheet 28, Rev. 1; Sheet 30, Rev. 2)

g. Plant Elect. Generation, Main One Line Diagram, BR3001: Sheet 1, Rev. 3; Sheet 2, Rev. 0

h. 480 V System One Line Diagram, BR3002: Sheet 1, Rev. 4; Sheet 2, Rev. 3; Sheet 3, Rev. 4; Sheet 4, Rev. 2

5. Ingersoll Rand Pumps, Gene Mills (IR) to F. Kuo (ESI), 5/12/92 (circulating water pump budgetary technical and cost information)

6. Marley Cooling Tower Company (budgetary cooling tower information):

a. S. Assman (MCT) to F. Kuo (ESI), 5/5/92: natural draft and round mechanical draft CT parametric technical and cost information for comparative study;

b. T. Dwyer (MCT) to F. DeSiervi (ESI), 6/3/92: budgetary technical, cost, environmental data for selected NDCT and RMDCT cases

c. T. Dwyer (MCT) to F. Kuo (ESI), ND and Round MDCT Noise Data, 6/4/92 (noise data for selected cases)

d. J. Van Garsse (MCT) to F. Kuo (ESI), Salt Water and Geothermal (Experience) Lists, 6/8/92

7. Engineering Weather Data, Department of the Army, TM5-785, 1 July 1978

LIST OF EXHIBITS

Exhibit 1
Oyster Creek NGS Site and Vicinity

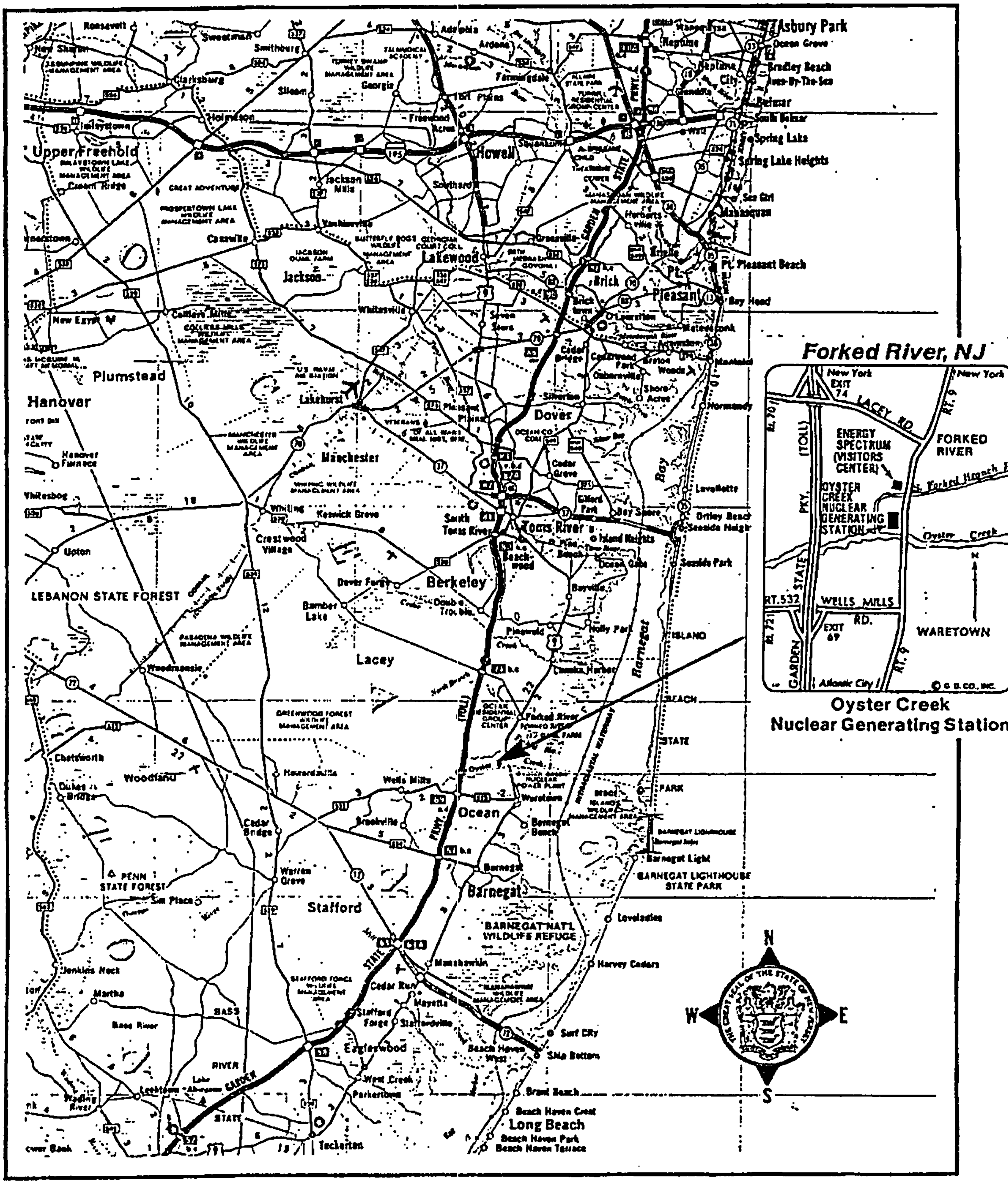


EXHIBIT 2

Existing Cooling Water System

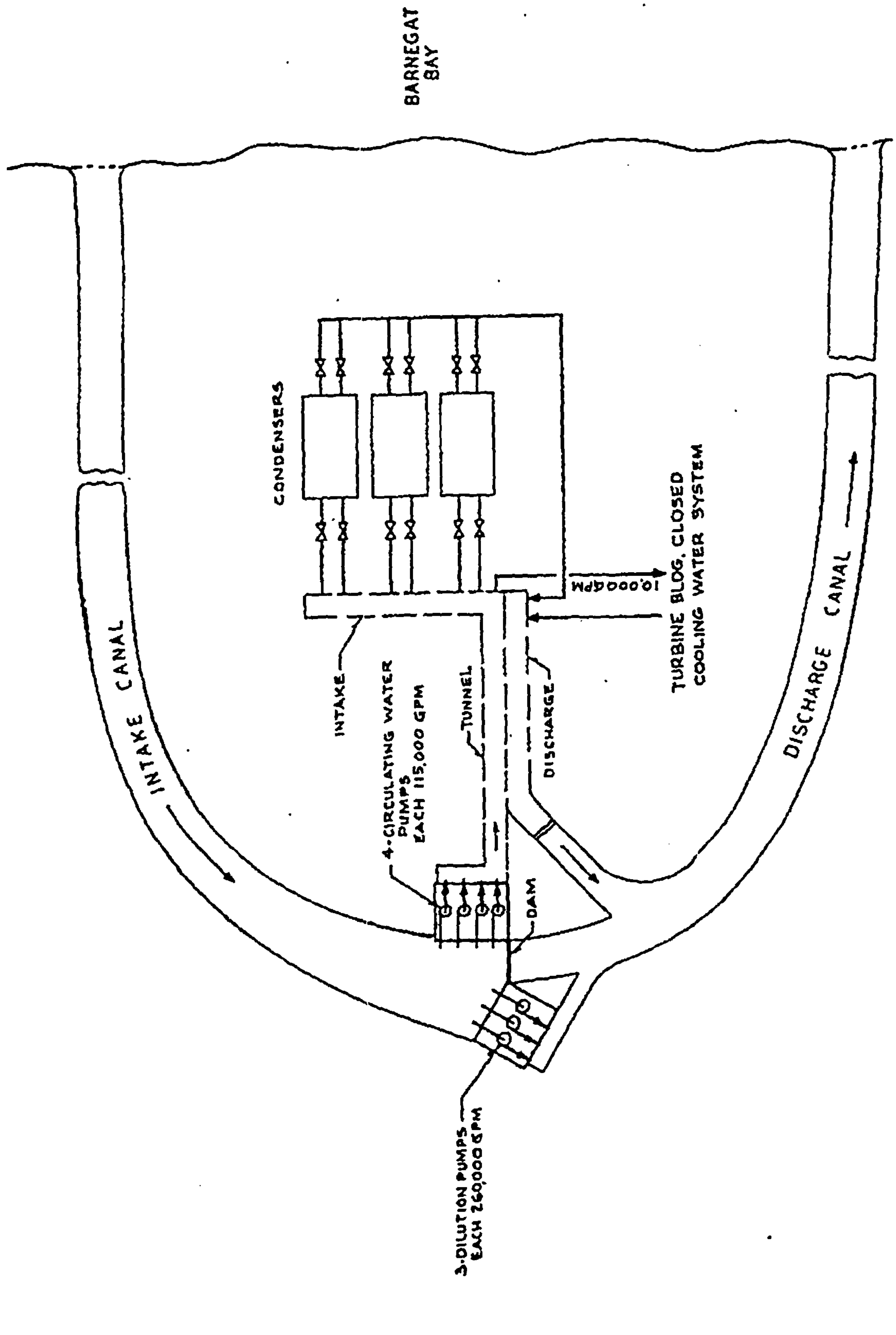


EXHIBIT 3

Condensing System Performance - Existing Cooling System

SPECIFICATIONS FOR CASE NO. 1 EXISTING ONCE THROUGH COOLING WATER SYSTEM — MHE DEPT A J HUSTO 06/10/92 PAGE 7

CW INLET DESIGN TEMPERATURE (F)	82.00	PERFORMANCE AT DESIGN CONDITIONS:		NO. OF COOLING TOWERS-CT	0
CONDENSER TEMPERATURE RISE (F)	18.26	TG CAPABILITY (MW)	616.81	NO. OF CELLS PER CT	0
TUBE DIAMETER (INCHES)/GAUGE	0.875/22	AVG CONDENSER PRESSURE (IN.HGA)	2.46	CT DESIGN APPROACH TEMP (F)	0.00
TOTAL TUBE LENGTH (FT/SHELL)	42.50			TOTAL CT FAN MOTOR INPUT KW	0
NO. OF: TUBES PER SHELL/SHELLS	14562/3			TOTAL CW PUMP MOTOR INPUT KW	3163
NO. OF: TUBE PASSES/PRESS ZONES	1/1	PERFORMANCE AT MAX SUMMER TEMP		CW PUMP MOTOR RATING (HP)	1000
TOTAL SURFACE AREA (SQ FT)	423000	TG CAPABILITY (MW)	610.31	CW SYSTEM TDH (FT)	28.53
CIRCULATING WATER FLOW (GPM)	450100	AVG CONDENSER PRESSURE (IN.HGA)	2.97	CW MAIN CONDUIT DIAM (FT)	10.50
TUBE VEL. AT ABOVE CW FLOW (FPS)	4.27			NO. OF CW PUMPS	4
		AVG SEASONAL COND PRESS (IN.HGA) 1.07 1.30 2.27		TG CAPABIL. @ WB 0.0F (MW)	0.0

E S T I M A T E D   I N I T I A L   I N V E S T M E N T   C O S T

ACCOUNT CODE	INITIAL INVESTMENT COST ITEMS	TODAY'S MATERIAL COST UNIT	TODAY'S MATERIAL COST TOTAL 1000$	TODAY'S INSTALLATION COST UNIT	TODAY'S INSTALLATION COST TOTAL 1000$	ESCALATION 1000$ MATERIAL	ESCALATION 1000$ INSTALLATION
	MAJOR SITE DEVELOPMENT	----------	0	----------	0	0	0
1.11	LOCAL IMPROVEMENT TO SITE-CLEARING	----------		0$/ACRE	0		0
2.1	LOCAL GRADING	----------		0.00$/CU YD	0		0
2.5	PILING	0.00$/SQ FT	0	0.00$/SQ FT	0	0	0
3.62	INTAKE STRUCTURE	0.00$/CU FT	0	0.0C$/CU FT	0	0	0
3.2	CIRCULATING WATER CONDUIT: MAIN	0$/LIN FT	0	0.00$/LIN FT	0	0	0
3.2	BRANCHES	0.00$/LIN FT	0	0.00$/LIN FT	0	0	0
3.32	DISCHARGE STRUCTURE	0.00$/CU FT	0	0.00$/CU FT	0	0	0
3.41	COOLING TOWER BASIN	0.00$/SQ FT	0	0.00$/SQ FT	0	0	0
3.44	COOLING TOWER SUPERSTRUCTURE	0$/EACH	0	0$/EACH	0	0	0
5.1	TG BUILDING (DIFFERENTIAL)	0$/FT HT	0	0$/FT HT	0	0	0
6.18	TG PEDESTAL (DIFFERENTIAL)	0$/FT HT	0	0$/FT HT	0	0	0
7.1	TG & ACCESSORIES (DIFFERENTIAL)	7.50$/KVA	0	0.0C$/KVA	0	0	0
10.211	CONDENSER SHELL	0$/EACH	0	0$/EACH	0	0	0
10.213	CONDENSER TUBE (TITAN)	0.0000$/FT	0	0.0000$/FT	0	0	0
10.221	CIRCULATING WATER PUMP	0$/EACH	0	0$/EACH	0	0	0
15.3	CIRCULATING WATER PUMP MOTOR	0$/EACH	0	0$/EACH	0	0	0
14.1	INSTRUMENTATION & CONTROL	0.00$/EACH	0	0.00$/EACH	0	0	0
15.11	START-UP & STANDBY TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.12	UNIT AUXILIARY TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.27	CIRCULATING WATER SWITCHGEAR	0$/PUMP	0	0$/PUMP	0	0	0
15.6	WIRING FOR CIRCULATING WATER SYSTEM	0$/MVA	0	0$/MVA	0	0	0
15.1	UNIT MAIN POWER TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	C$/MVA	0	0	C
15.23	FAN MOTOR POWER CENTER + REQ'D SWGR & FEEDER	0$/CENTER	0	0$/CENTER	0	0	0
	TOTAL		0		0	0	0

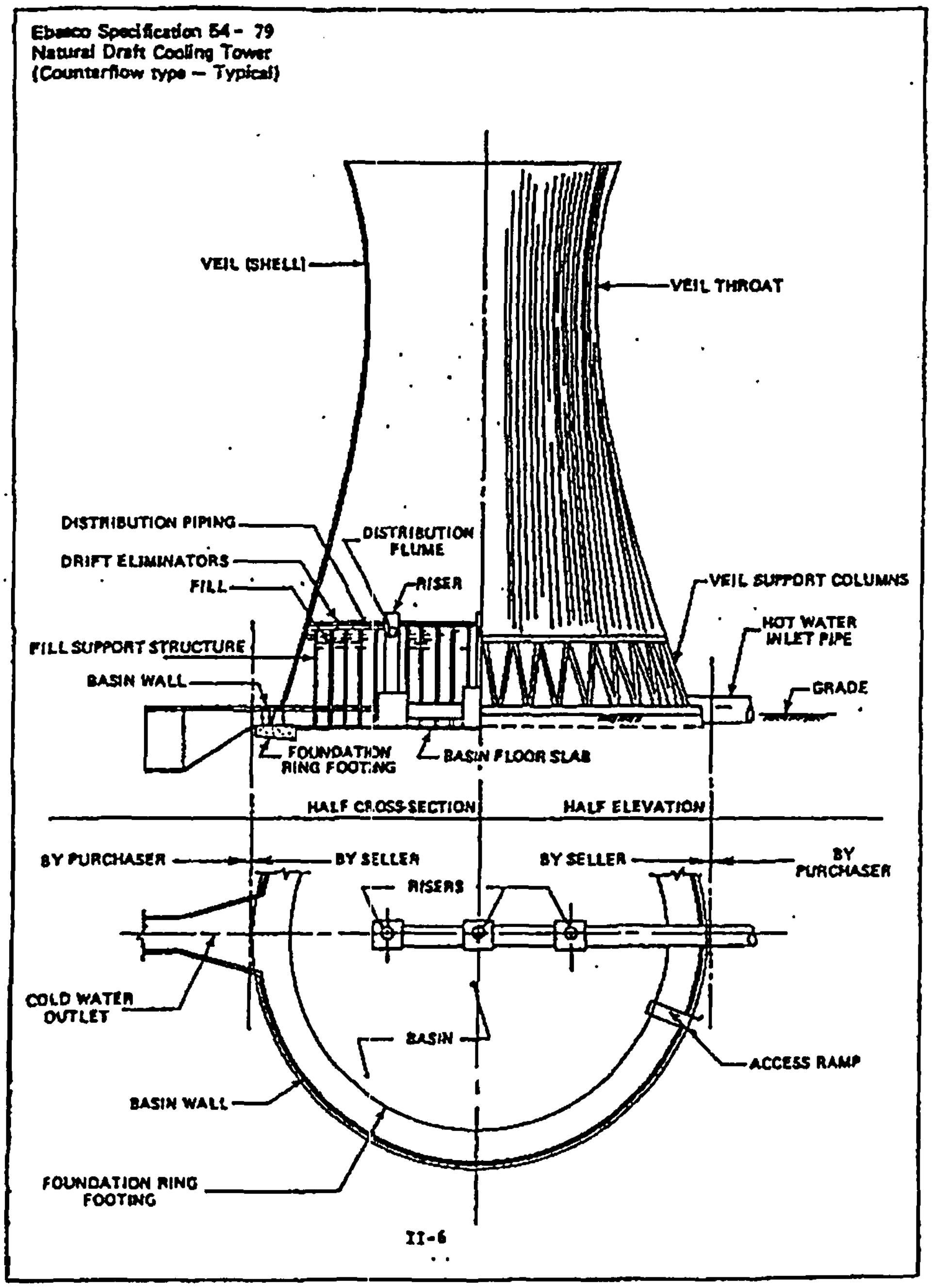
TOTAL DIRECT ESCALATED COST: MATERIAL PLUS ***** % SALES/USE TAX PLUS INSTALLATION	0
INDIRECT CONSTRUCTION COST INCLUDING PROFESSIONAL SERVICES	0
CONTINGENCY (14.00% OF DIRECT PLUS INDIRECT COST)	0
UTILITY'S EXPENSES, INTEREST DURING CONSTRUCTION, & LAND	0
TOTAL ESTIMATED INVESTMENT COST 1000$	0

E S T I M A T E D   C O M P A R A B L E   I N V E S T M E N T   &   A N N U A L   C O S T S

			1000$/YR	MILLS/KWH
UNIT NET CAPABIL. W/SF/S/P (MW) 621.1 618.9 605.1 587.6		CW SYSTEM FUEL COST (BASE VALUE)	0	
DIFFERENTIAL UNIT NET CAPABILITY (MW)	0.05	ANNUAL FIXED CHARGES (AT RATE 0.2225)	0	
		WATER COST (AT 0.$/MILLION GALLONS + CHEMICALS)	0	
UNIT NET ANNUAL GENERATION (MWH/YR)	4039129	MAINTENANCE (0.00% OF TOTAL INV + 0$/FAN)	0	
DIFFERENTIAL UNIT NET GENERATION (MWH/YR)	0	SUBTOTAL ANNUAL COST	0	
		NET PRODUCTION COST		0.000
WATER CONSUMPTION (MILLION GALLONS/YR)	0			
		ADJUSTMENT FOR DIFFERENTIAL CAPABILITY	0	
TOTAL ANNUAL UNIT FUEL COST		ADJUSTMENT FOR DIFFERENTIAL NET ANNUAL GENERATION	0	
(AT 0.0000$/MILLION BTU) (1000$)	0	TOTAL COMPARABLE ANNUAL COST INCLUDING ADJUSTMENTS		
TOTAL COMPARABLE INVESTMENT COST		FOR EQUALIZED CAPABILITY & NET ANNUAL GENERATION	0	
INCLUDING CAPABILITY ADJUSTMENT (1000$)	0	COMPARABLE NET PRODUCTION COST INCL. ADJUSTMENTS		0.000

EXHIBIT 4

Natural Draft Cooling Tower General Arrangement



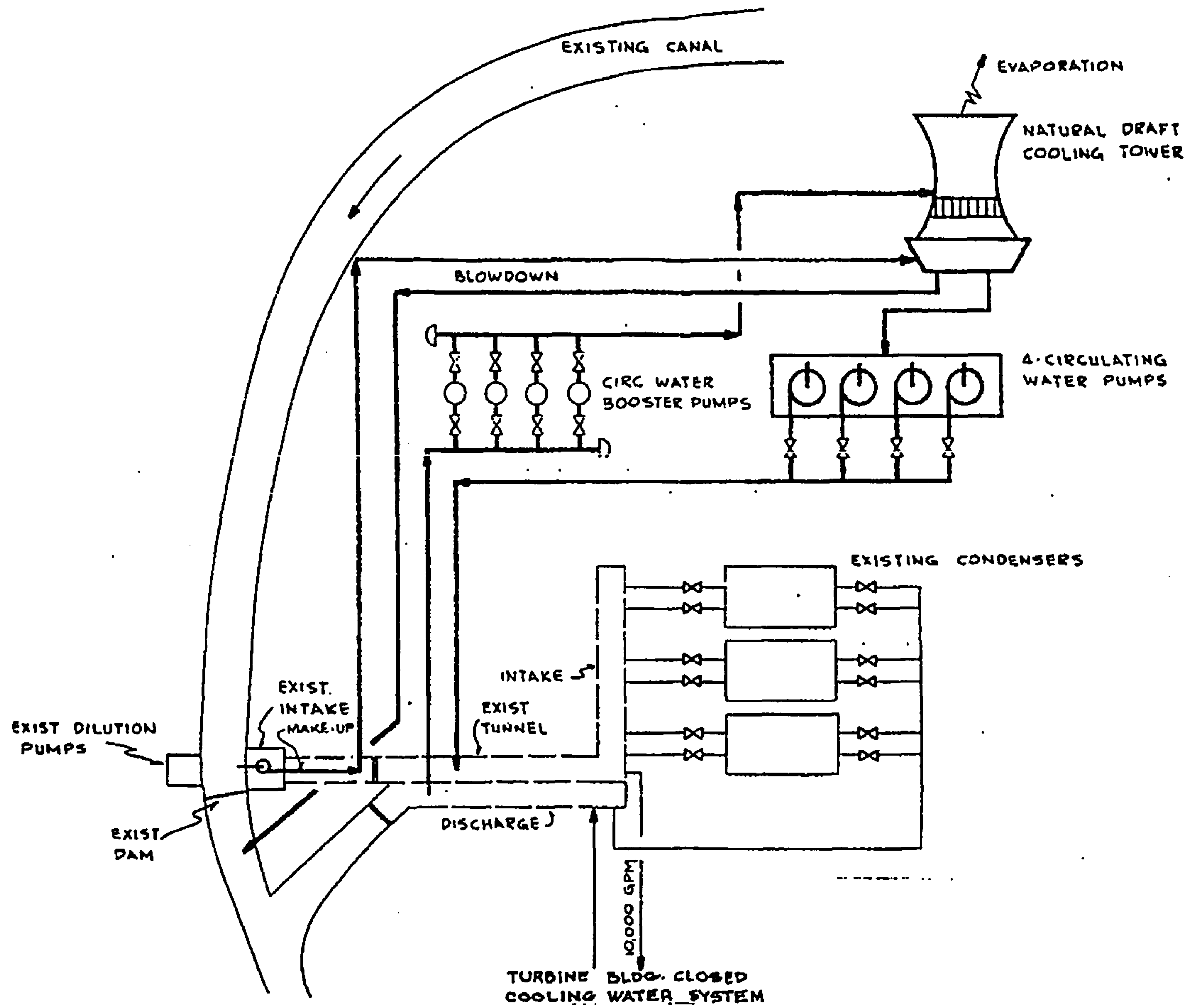


EXHIBIT 5
Natural Draft Cooling System Flow Diagram

EXHIBIT 6

Natural Draft Cooling System Layout

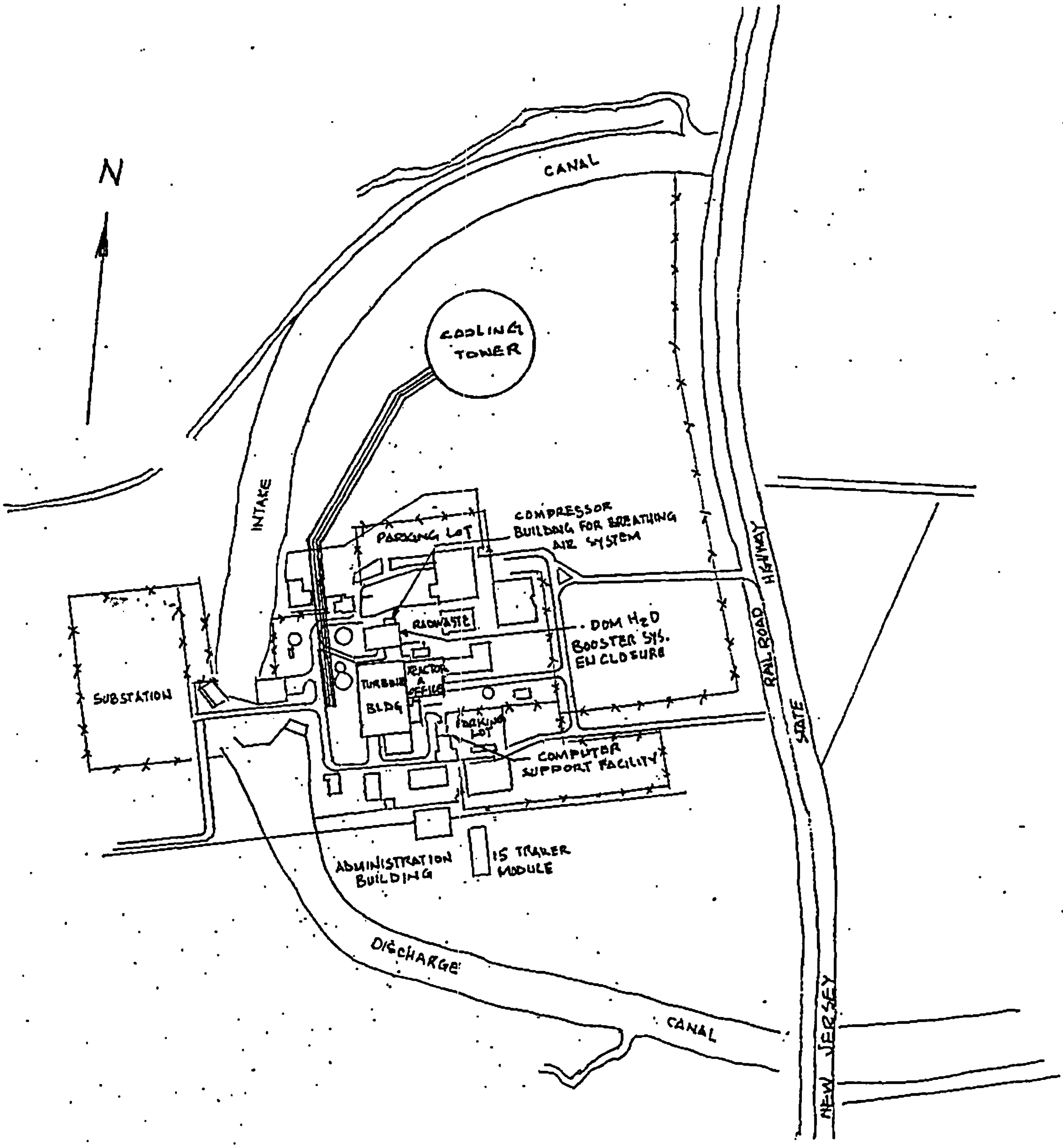


EXHIBIT 7

CWS Hydraulic Gradient - NDCT

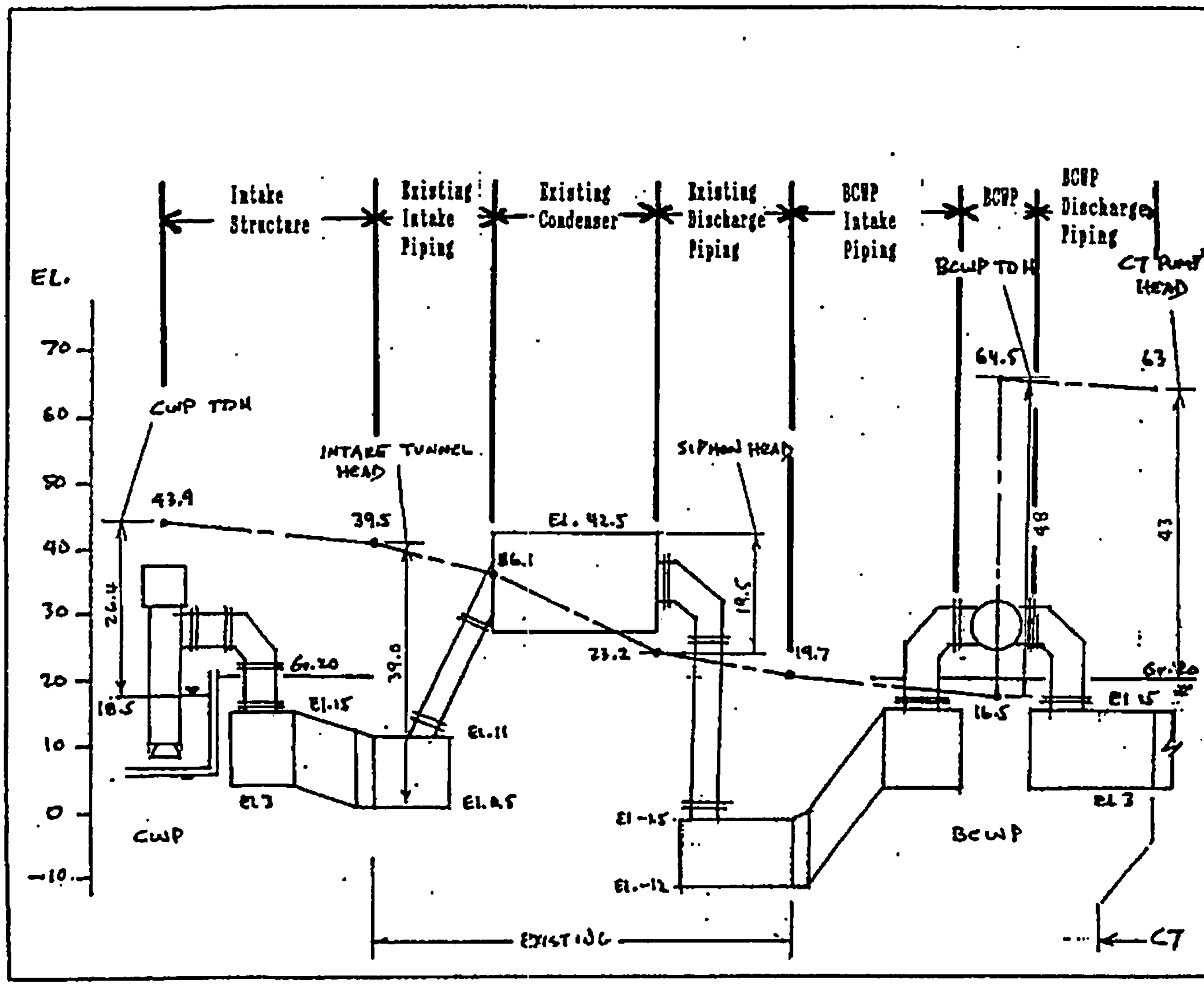


EXHIBIT 8

One Line Diagram - NDCT Power Supply

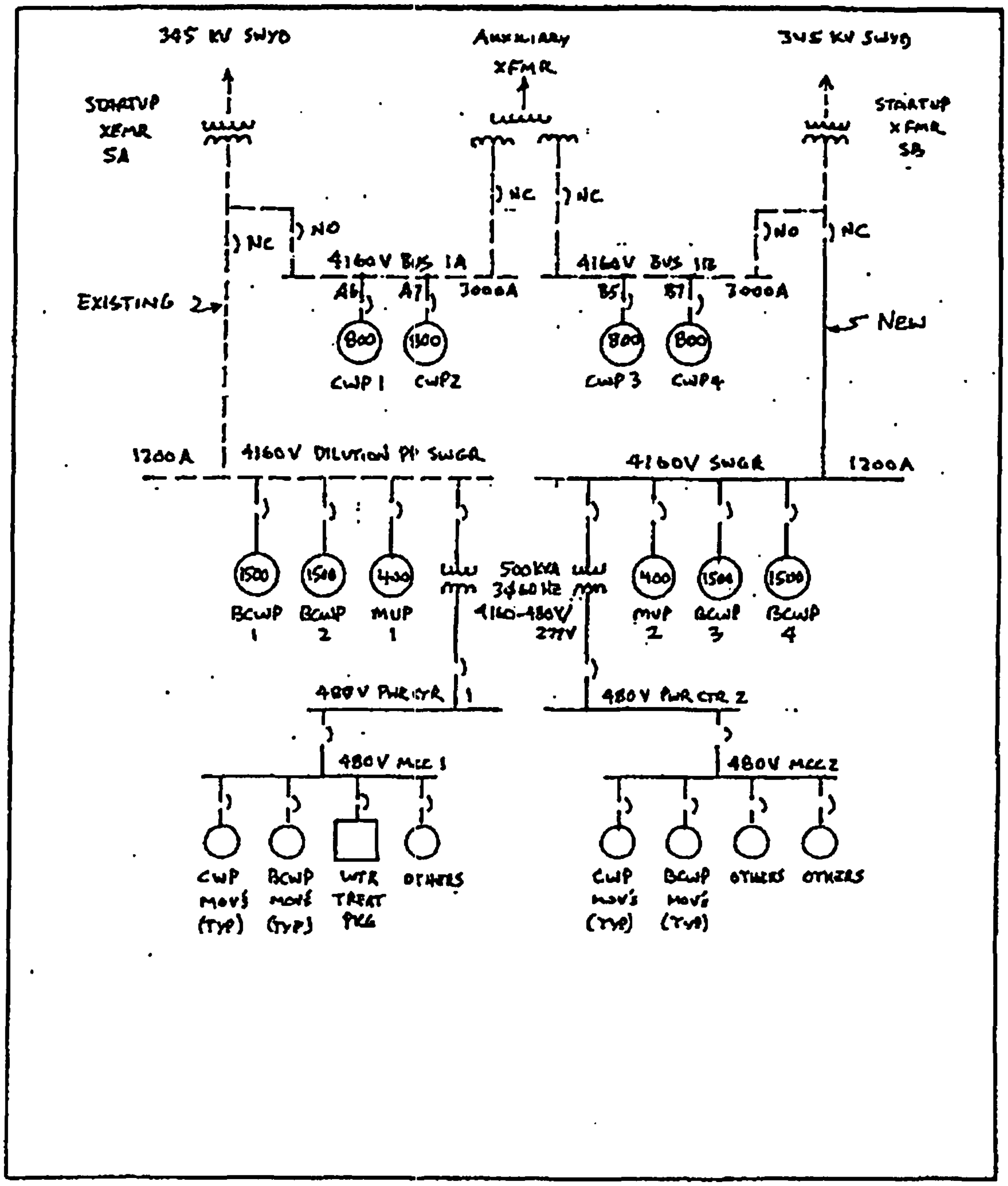


EXHIBIT 9

Circulating Water Quality Analysis - NDCT

Cations	Raw Water as Ions ppm	Concen as CaCO3 ppm	Recirc Wtr as Ions ppm	Concen as CaCO3 ppm
Calcium	180	448.88	360	897.76
Magnesium	375	1543.21	750	3086.42
Potassium	256	327.37	512	654.73
Sodium	8033.62	17464.39	16067.24	34928.78
Total cations	8844.62	19783.84	17689.24	39567.69
Anions				
Bicarbonate	42.7	35.00	70	57.38
Carbonate	0	0.00	0	0.00
Sulfate	1816	1889.70	3644.12	3782.01
Chloride	12680	17859.15	25360	35718.31
Fluoride	0	0.00	0	0.00
Nitrate	0	0.00	0	0.00
Total anions	14538.7	19783.85	29074.12	39567.69
Silica, ppm	18	14.94	36	29.88
Iron, ppm	0.6	1.07	1.20	2.15
Manganese, ppm	0.01	0.02	0.02	0.04
Carbon Dioxide, ppm	7.84	8.93	2.00	2.28
Aluminum, ppb	0.000		0.000	
Cadminum, ppb	0.000		0.000	
Copper, ppb	0.000		0.000	
Chrominum, ppb	0.000		0.000	
Fluorine, ppb	0.000		0.000	
Nickel, ppb	0.000		0.000	
Vanadium, ppb	0.000		0.000	
Zinc, ppb	0.000		0.000	
T degrees F	65		106.2	
T degrees C	18.33		41.22	
M alkalinity (CaCO3)	35.00		57.38	
pH measured	6.95		7.66	
Neutral pH	7.11		6.75	
TDS, ppm	23409.766		46802.58	
Langelier Index	-1.39		0.48	
Ryznar Index	9.73		6.73	
Using the LI-This water is	Corrosive		Scale Forming	
Concentration factor	11.01		5.11	
Conductivity,microhms/cm	29630.65		99251.04	
Cycles of Concentration	2			
Sulfuric acid required	1191.53 LBS/DAY		81.06 GALS/DAY	
Sodium for balance	8033.62			

COOLING TOWER CALCULATION

AMBIENT CONDITION	89 °F
RECIRCULATION RATE	416,200 GPM
INLET TEMP T1	86 °F
OUTLET TEMP T2	106.2 °F
TEMP DIFF.	20.2 °F
WET BULB TEMP	74 °F
EVAPORATION RATE	7,491.60 GPM
CYCLES OF CONCEN	2
DRIFT	4.16 GPM
BLOWDOWN	7,487.44 GPM
MAKEUP	14,983.20 GPM

EXHIBIT 10

Water Treatment System Schematic Diagram

NDCT and RMDCT

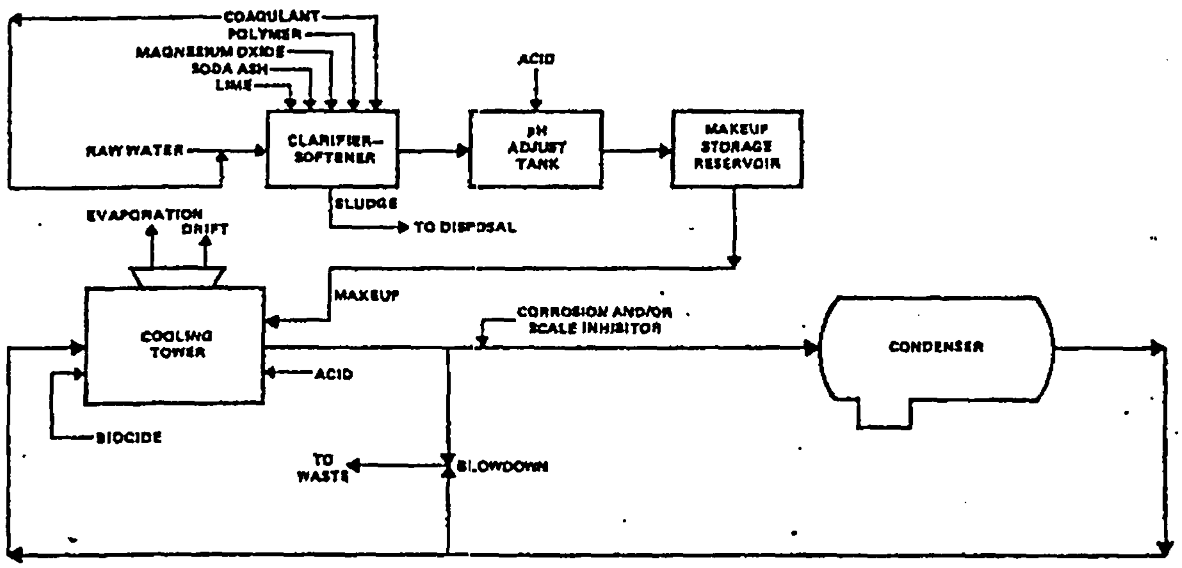
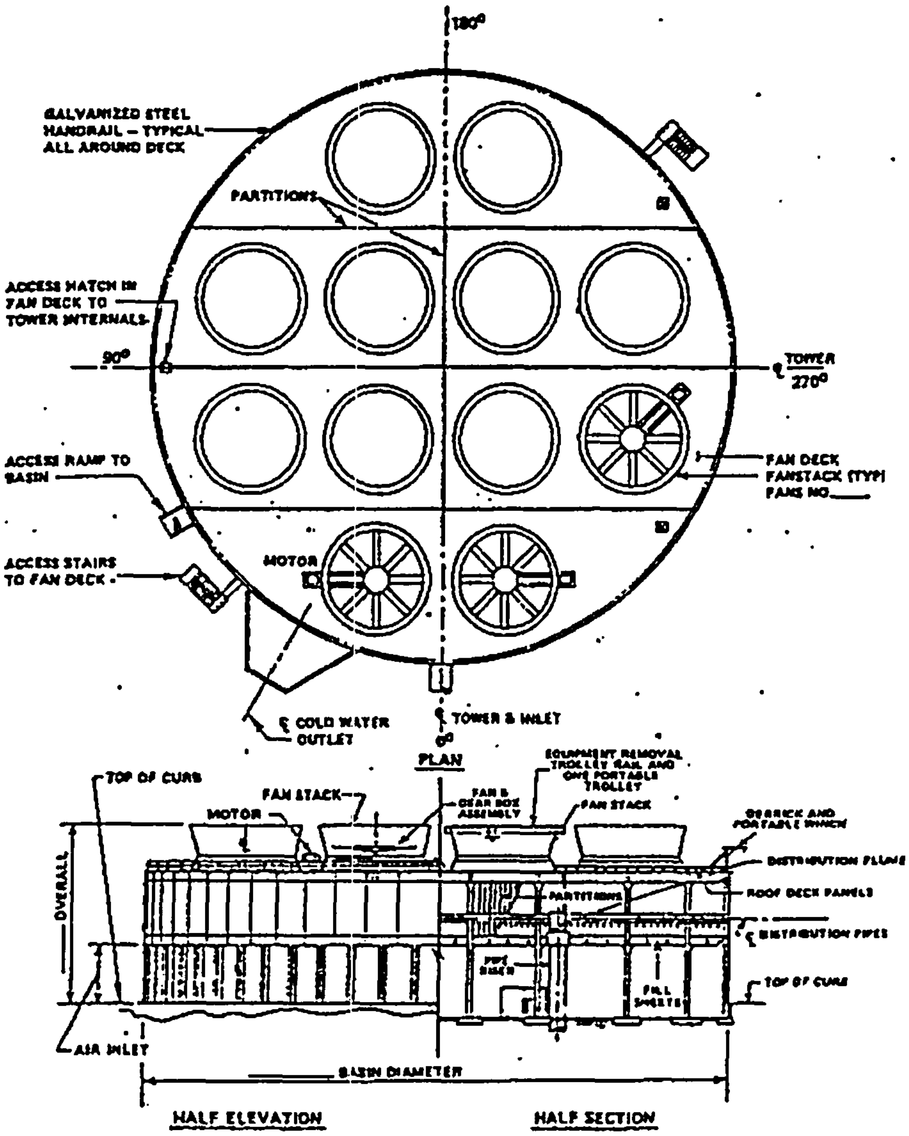


EXHIBIT 11

Round Mechanical Draft Cooling Tower General Arrangement

Ebasco Specification
Mechanical Draft Cooling Tower
(Counterflow Type – Typical Round Concrete)



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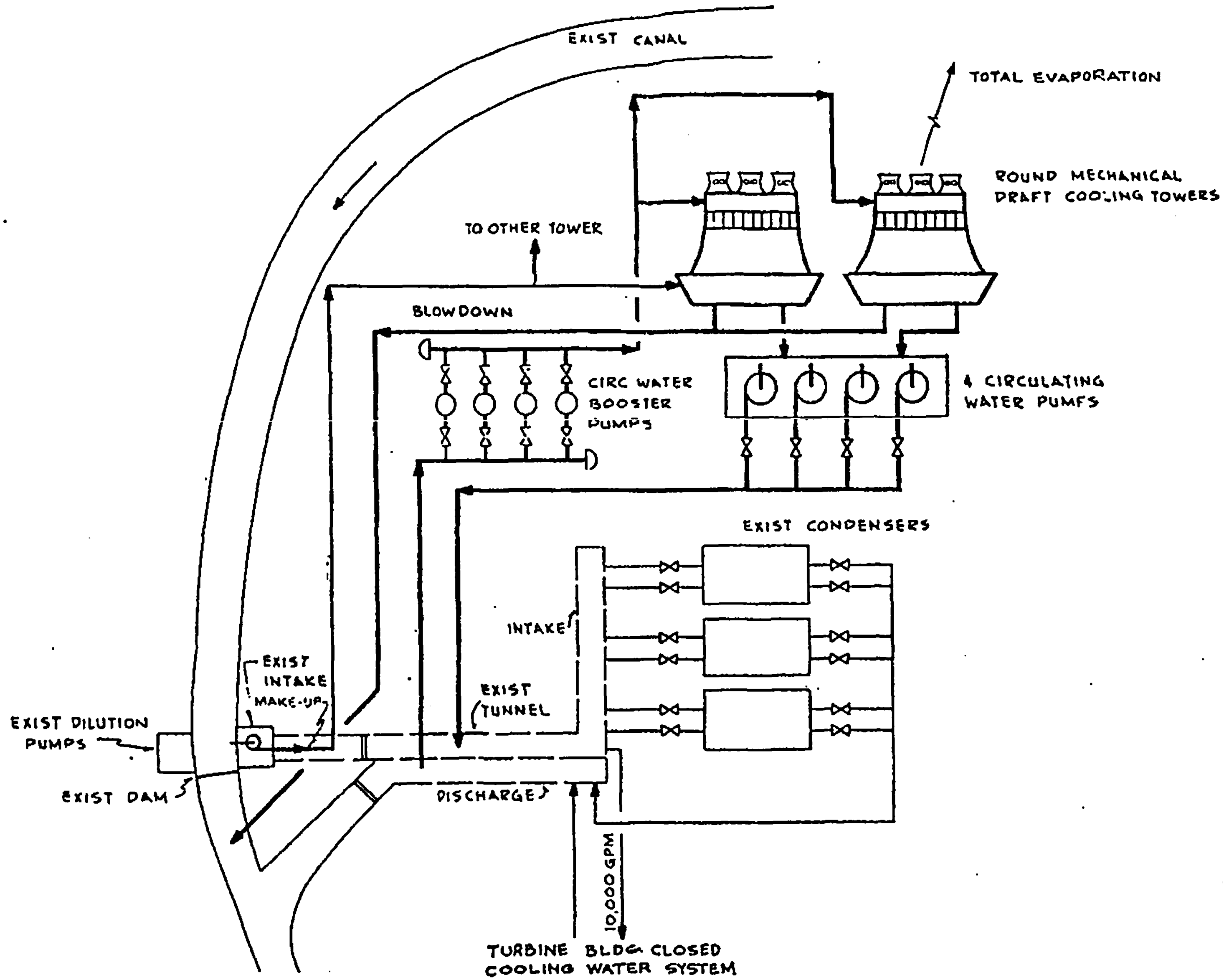


EXHIBIT 12
Round Mechanical Draft Cooling System Flow Diagram

EXHIBIT 13

Round Mechanical Draft Cooling System Layout

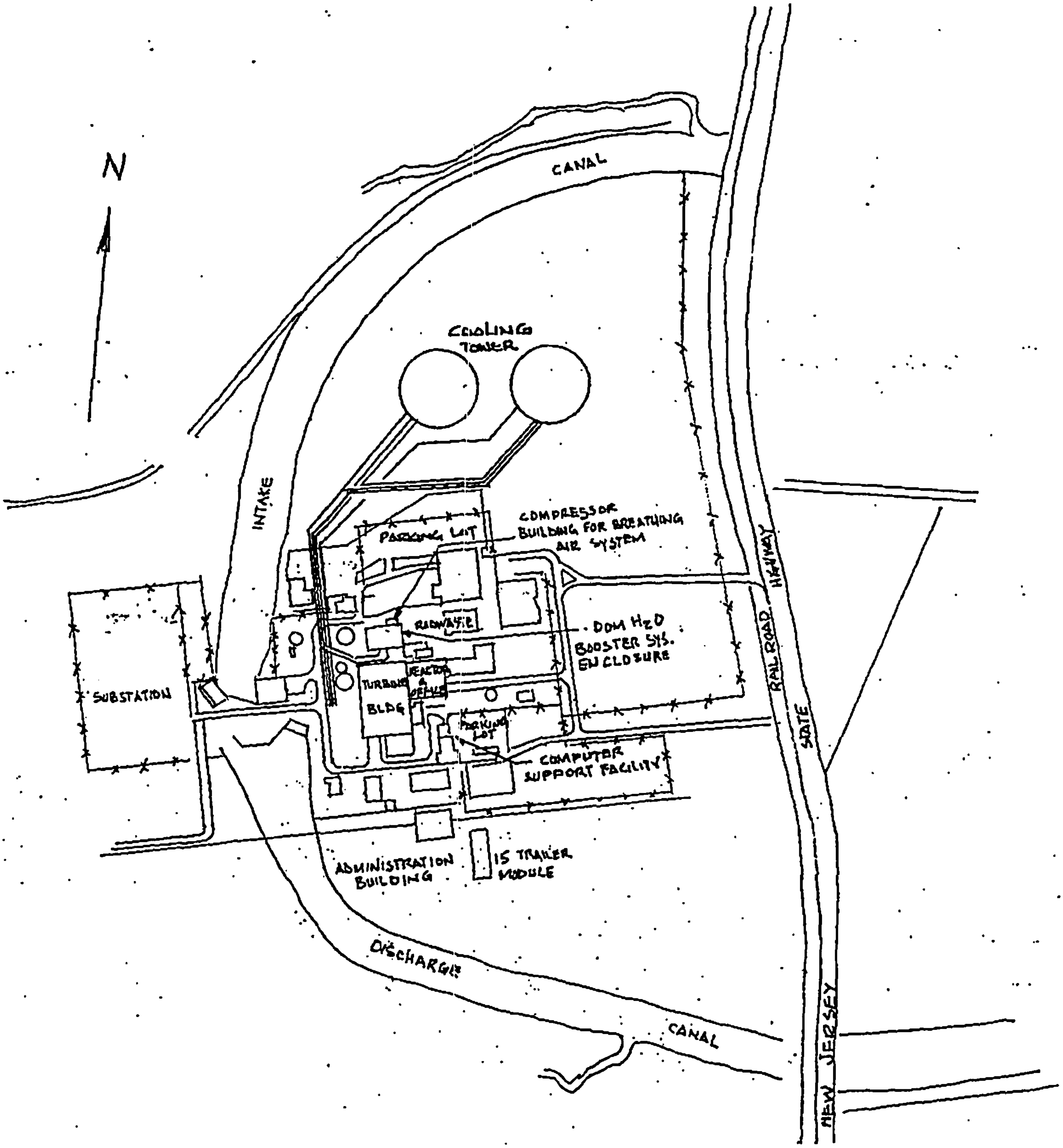


EXHIBIT 14

CWS Hydraulic Gradient - RMDCT

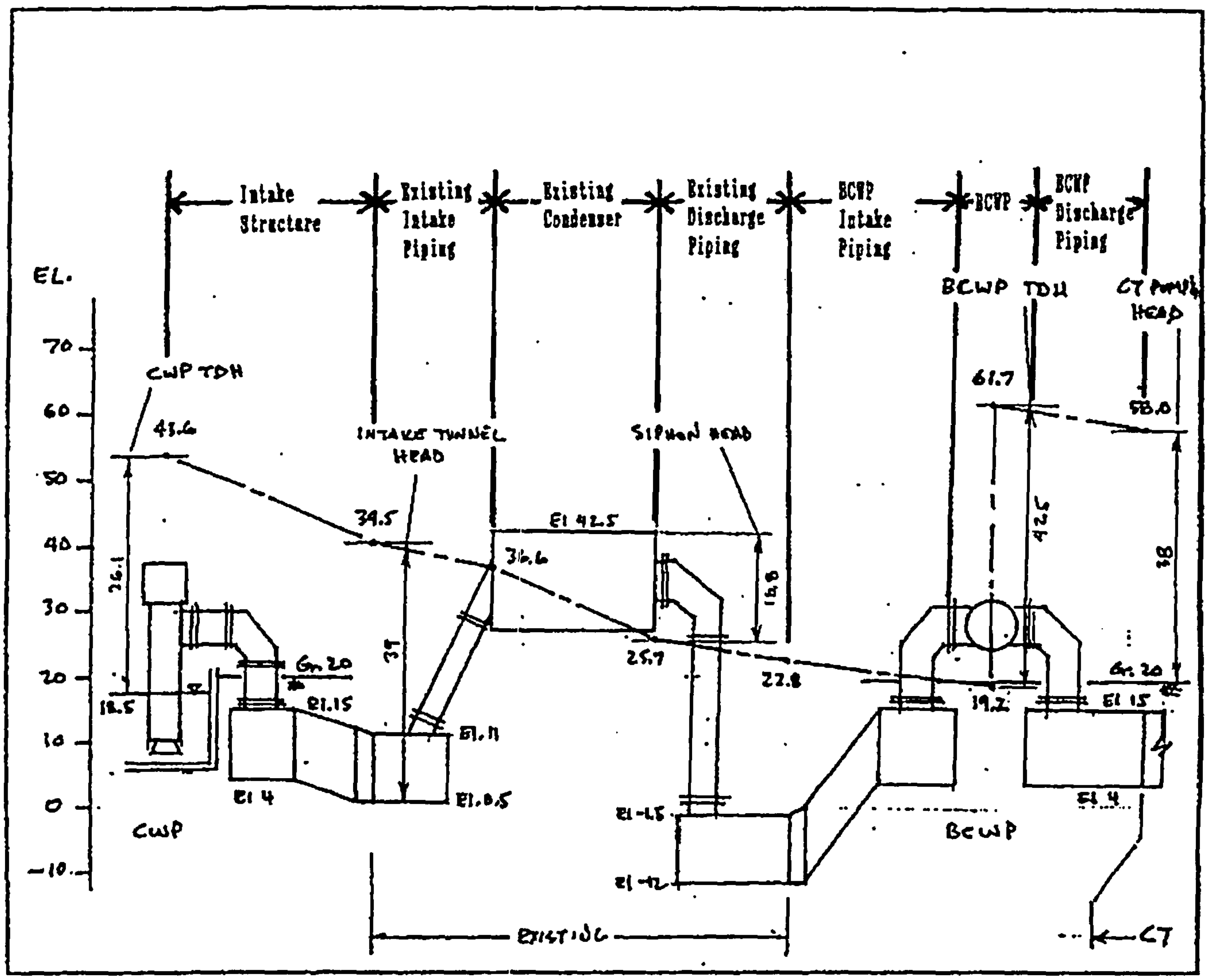


EXHIBIT 15

One Line Diagram - RMDCT Power Supply

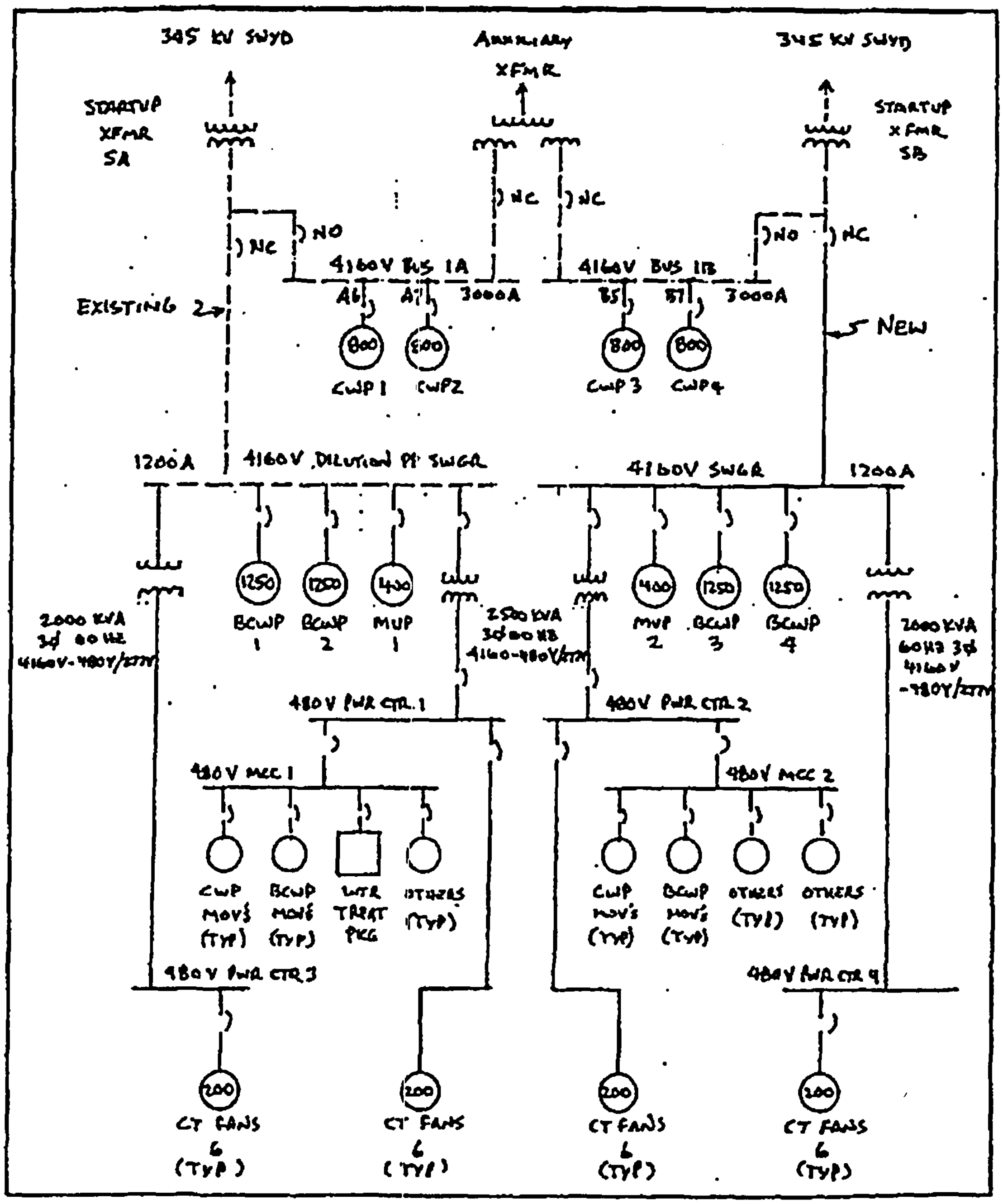


EXHIBIT 16

Circulating Water Quality Analysis - RMDCT

Cations	Raw Water as ions ppm	Concen Recirc Wtr as CaCO3 ppm	as ions ppm	Concen as CaCO3 ppm
Calcium	180	448.88	360	897.76
Magnesium	375	1543.21	750	3086.42
Potassium	256	327.37	512	654.73
Sodium	8033.62	17464.39	16067.24	34928.78
Total cations	8644.62	19783.84	17689.24	39567.69
Anions				
Bicarbonate	42.7	35.00	70	57.38
Carbonate	0	0.00	0	0.00
Sulfate	1816	1889.70	3644.12	3792.01
Chloride	12680	17859.15	25360	35718.31
Fluoride	0	0.00	0	0.00
Nitrate	0	0.00	0	0.00
Total anions	14538.7	19783.85	29074.12	39567.69
Silica, ppm	18	14.94	36	29.88
Iron, ppm	0.6	1.07	1.20	2.15
Manganese, ppm	0.01	0.02	0.02	0.04
Carbon Dioxide, ppm	7.84	6.93	2.00	2.28
Aluminum, ppb	0.000		0.000	
Cadminum, ppb	0.000		0.000	
Copper, ppb	0.000		0.000	
Chrominum, ppb	0.000		0.000	
Fluorine, ppb	0.000		0.000	
Nickel, ppb	0.000		0.000	
Vanadium, ppb	0.000		0.000	
Zinc, ppb	0.000		0.000	
T degrees F	65		106.6	
T degrees C	18.33		41.44	
M alkalinity (CaCO3)	35.00		57.38	
pH measured	6.95		7.66	
Neutral pH	7.11		6.75	
TDS, ppm	23409.766		46802.58	
Langelier index	-1.39		0.47	
Ryznar index	9.73		6.72	
Using the LI-This water is	Corrosive		Scale Forming	
Concentration factor	11.01		5.11	
Conductivity, microhms/cm	29630.65		99624.09	
Cycles of Concentration	2			
Sulfuric acid required	1222.43 LBS/DAY		83.16 GALS/DAY	
Sodium for balance	8033.62			

COOLING TOWER CALCULATION

AMBIENT CONDITION	89 °F
RECIRCULATION RATE	373,100 GPM
INLET TEMP T1	84 °F
OUTLET TEMP T2	106.6 °F
TEMP DIFF.	22.6 °F
WET BULB TEMP	74 °F
EVAPORATION RATE	7,685.86 GPM
CYCLES OF CONCEN	2
DRIFT	3.73 GPM
BLOWDOWN	7,682.13 GPM
MAKEUP	15,371.72 GPM

EXHIBIT 17

Levelized Energy and Demand Charge

Rate of Return: 10.78%

Year	Energy Value	Capacity Charge	Total	Present Wrth Fct	Present Value
1991	28.00	7.25	35.25		
1992	28.90	7.63	36.53		
1993	32.30	8.02	40.32		
1994	32.90	8.44	41.34		
1995	38.20	8.89	47.09	1.0000	47.09
1996	42.40	9.41	51.81	0.9027	46.77
1997	46.20	9.96	56.16	0.8148	45.76
1998	50.00	10.56	60.56	0.7356	44.55
1999	55.50	11.21	66.71	0.6640	44.29
2000	60.60	11.90	72.50	0.5994	43.45
2001	57.30	12.65	69.95	0.5410	37.85
2002	71.00	13.45	84.45	0.4884	41.24
2003	78.50	14.30	92.80	0.4409	40.91
2004	88.20	15.20	103.40	0.3980	41.15
2005	96.30	16.15	112.45	0.3592	40.40
2006	103.50	17.19	120.69	0.3243	39.14
2007	113.00	18.31	131.31	0.2927	38.44
2008	117.50	19.50	137.00	0.2642	36.20
2009	144.40	20.74	165.14	0.2385	39.39
Sum				8.0637	626.63

Levelized Replacement Power Cost = \$ 626.63 Mweh / 8.0637

= \$ 77.71 / Mweh

Reference #2d: Informatiom from GPUN, T. Ruggiero (GPUN) to F. Kuo (ESI) on 4/7/92. Replacement Power Costs (\$/Mweh), 1991 to 2009, dated 5/1/91.

EXHIBIT 18

Intake Water Average Monthly & Seasonal Temperatures

Year	1976	1977	1978	1979	1980	Average '76-80
Annual Mean Temp. F						
	57.9	57.4	56.3	58.5	56.5	57.3
Monthly Average Temp. F						
January	33.1	32.2	34.9	37.0	35.4	34.5
February	39.4	35.8	34.5	34.5	33.3	35.5
March	48.2	47.3	41.7	47.7	39.9	45.0
April	57.9	57.4	53.2	54.3	53.6	55.3
May	68.0	65.1	60.3	66.4	62.8	64.5
June	78.4	70.5	73.2	74.8	70.9	73.6
July	80.1	78.4	77.0	77.7	79.2	78.5
August	79.9	79.5	78.8	79.0	79.7	79.4
September	73.9	72.5	69.4	73.2	75.6	72.9
October	58.8	58.1	59.5	61.2	60.6	59.6
November	44.2	51.1	51.1	52.9	46.2	49.1
December	32.2	39.2	40.3	40.6	38.3	38.1
Seasonal Average Temperature, F						
Summer (J,J,A,S)	78.1	75.3	74.7	76.2	76.4	76.1
Spring /Fall (M,A,M,O,N)	55.5	55.8	53.2	56.5	52.7	54.7
Winter (D,J,F)	34.8	35.7	36.6	37.5	35.7	36.1

Reference: The Ichthyofauna of Barnegat Bay, New Jersey - Relationships between Long Term Temperature Fluctuations and the Population Dynamics and Life History of Temperature Estuarine Fishes During a Five Year Period, 1976-1980 by James J Vouglitois Thesis submitted to The Graduate School of Rutgers, The State University of New Jersey, January 1983.

EXHIBIT 19
Ambient Air Temperatures

Month	Dew Point (F)	Dry Bulb (F)	Wet Bulb (F)
January	20.2	28.1	25.0
February	28.4	36.7	33.5
March	29.9	41.2	36.7
April	39.5	51.3	45.0
May	50.3	61.3	55.0
June	59.6	71.0	63.5
July	64.7	76.8	68.5
August	64.1	74.2	67.5
September	57.5	66.8	61.0
October	49.3	57.1	52.5
November	39.7	47.5	43.2
December	29.2	37.5	34.0

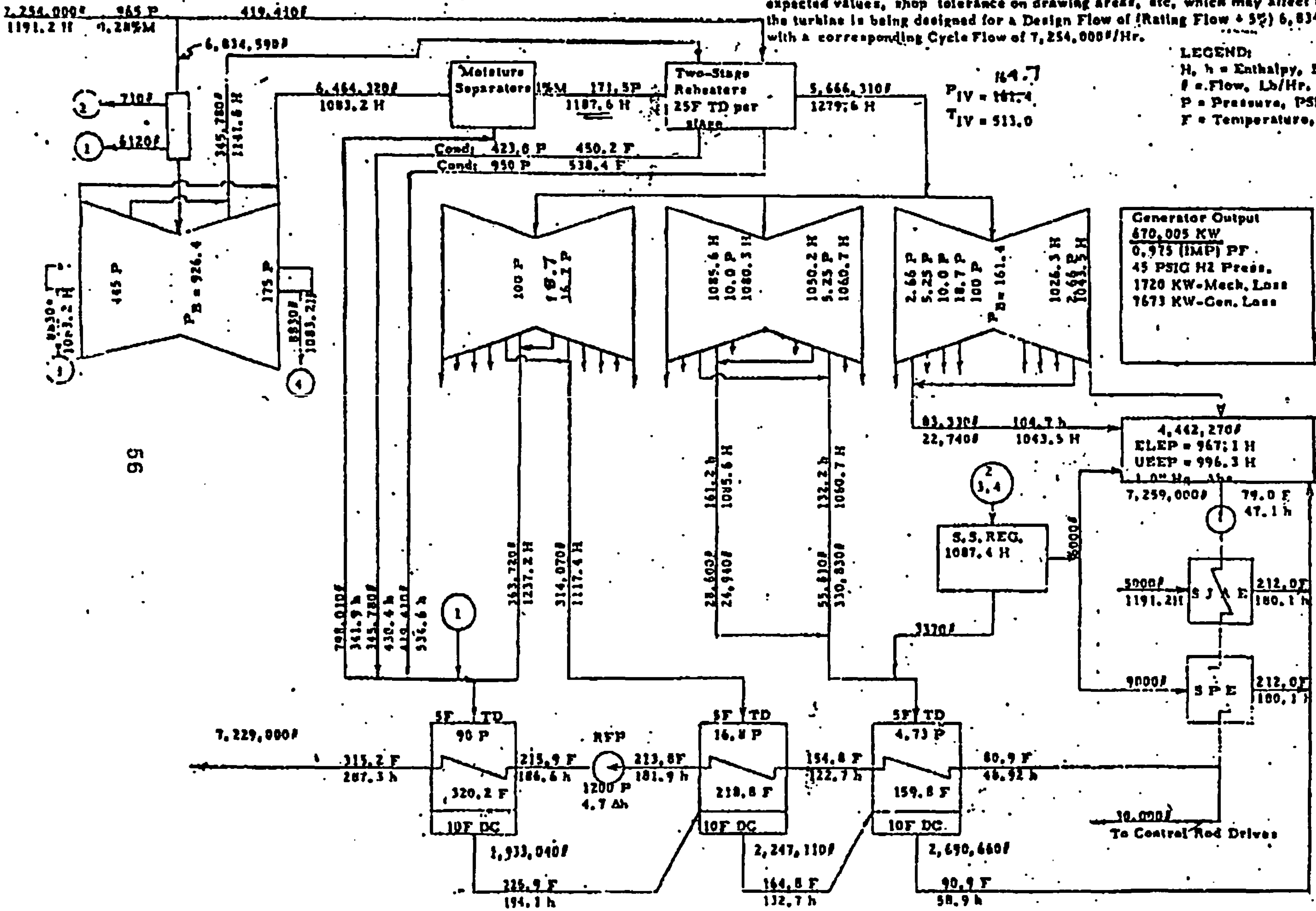
Cooling tower design and average seasonal wet bulb temperatures used in determining circulating water temperatures are:

Ambient Condition	Wet Bulb Temp. F
Cooling tower design	74 F
Average summer (Jun, Jul, Aug, Sep)	65 F
Average spring/fall (Mar, Apr, May, Oct, Nov)	47 F
Average winter (Dec, Jan, Feb)	31 F

Reference: National Climatic Data Center in Asheville, NC CD-144 Format 1981 to 1985 for Atlantic City, NJ Airport

CALCULATED DATA - NOT GUARANTEED

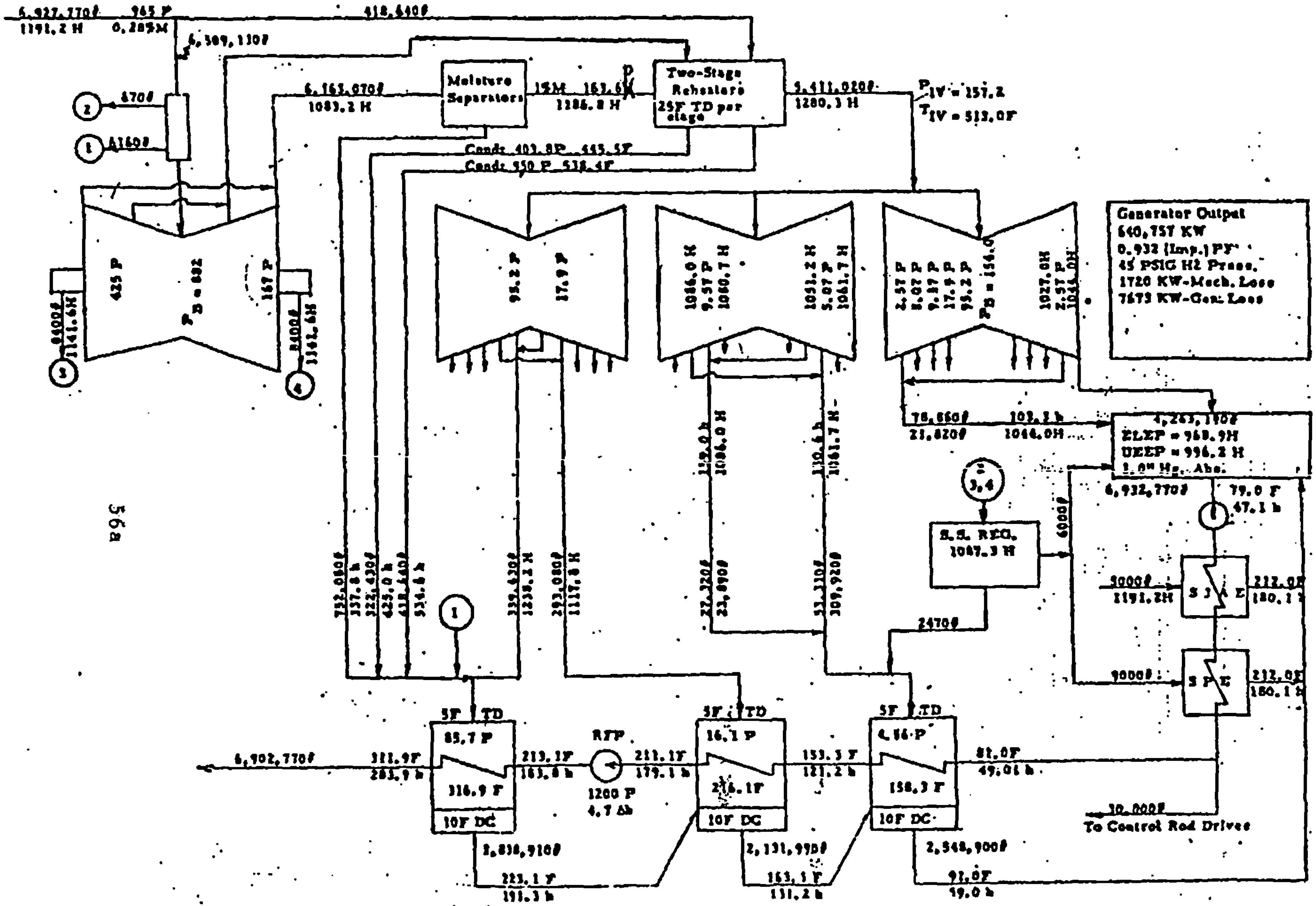
Turbine Rating Flow (Guaranteed) is 6,509,130#/Hr. with a corresponding Cycle Flow of 6,927,770#/Hr. at inlet steam conditions of 965 PSIA 0.28% M. To assure that the turbine will pass this flow, considering variations in flow coefficients from expected values, shop tolerance on drawing areas, etc. which may affect the flow, the turbine is being designed for a Design Flow of (Rating Flow + 5%) 6,834,590#/Hr. with a corresponding Cycle Flow of 7,254,000#/Hr.



GROSS HEAT RATE = $\frac{7,254,000\ (1191.2 - 287.3) + 30,000\ (287.3 - 48.92)}{670,005}$ = 9797 BTU/KW-HR

EXHIBIT 20a
Turbine Cycle Heat Balance
Valves Wide Open

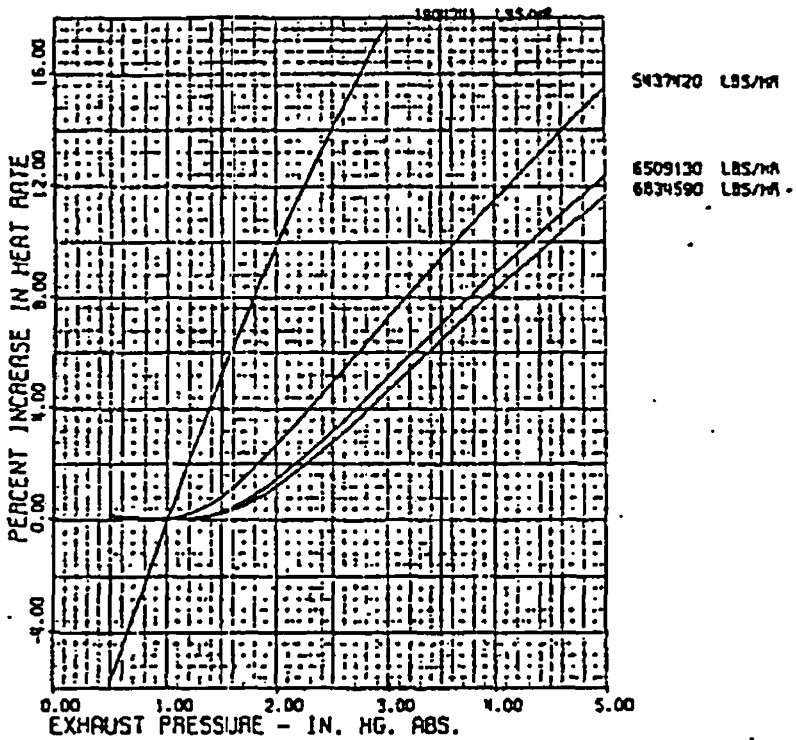
EXHIBIT 20b
Turbine Cycle Heat Balance
100% Load



GROSS HEAT RATE = $\frac{6,927,770\ (1191.2 - 283.9) + 10,000\ (283.9 - 49.01)}{640,757}$ = 9821 BTU/KW-HR

EXHIBIT 21
Exhaust Pressure Correction Curve

640.700 KW 1.0 IN. HG. ABS. 0 PCT MU
TC6F-38 IN. LSB 1800 RPM
950 PSIG 1191.2 H 0.28 H



METHOD OF USING CURVE

FLOWS NEAR CURVES ARE THROTTLE FLOWS AT 950 PSIG 1191.2 H
THESE CORRECTION FACTORS ASSUME CONSTANT CONTROL VALVE OPENING
APPLY CORRECTIONS TO HEAT RATES AND KW LOADS
AT 1.0 IN. HG. ABS. AND 0 PCT MU

THE PERCENT CHANGE IN KW LOAD FOR VARIOUS EXHAUST PRESSURES IS EQUAL TO
(MINUS PCT INCREASE IN HEAT RATE)100/(100 + PCT INCREASE IN HEAT RATE)

THESE CORRECTION FACTORS ARE NOT GUARANTEED

GENERAL ELECTRIC COMPANY. SCHENECTADY. NEW YORK

EXHIBIT 22
Cooling Tower Parametric Data - NDCT

Heat Duty, 10E6 Btu/hr 4300 Design Wet Bulb, 74 F
Cooling Water Seawater

Range, F	16	16	16	16
Approach, F	10	12	14	16
CW Flow, gpm	554,100	554,100	554,100	554,100
Marley Model No.				
Number of Towers				
Diameter, ft	Too difficult for natural draft cooling tower			
Height, ft				
Pumping Head, ft				
L/G Ration				
Evaporation Loss, %				
Price, $ million				

Range, F	20	20	20	20
Approach, F	10	12	14	16
CW Flow, gpm	443,200	443,200	443,200	443,200
Marley Model No.		8600237 -5.5-410	8550232 -5.0-406	8550222 -4.5-369
Number of Towers		1	1	1
Diameter, ft	Too	415	411	374
Height, ft	difficult	600	550	550
Pumping Head, ft	for	42	42	38
L/G Ratio	NDCT	1.803	1.87	2.04
Evaporation Loss, %		1.8	1.8	1.8
Price, $ million		23.11	22.25	19.61

Range, F	24	24	24	24
Approach, F	10	12	14	16
CW Flow, gpm	369,400	369,400	369,400	369,400
Marley Model No.	8570237 -5.0-410	8550237 -4.5-393	8550227 -4.5-352	8500212 -4.5-3xx
Number of Towers	1	1	1	1
Diameter, ft	415	398	356	338
Height, ft	570	550	550	500
Pumping Head, ft	44	43	40	38
L/G Ratio	1.46	1.52	1.69	1.89
Evaporation Loss, %	2.2	2.2	2.1	2.1
Price, $ million	22.725	21.215	18.48	16.56

Reference 6a: Marley Cooling Tower Company, S. Assman (MCT) to F. Kuo (ESI) on 5/5/92 - Natural Draft and Round Mechanical Draft CT Parametric Technical and Cost Information For Comparative Study

EXHIBIT 23

Cooling Tower Parametric Data - RMDCT

Heat Duty, 10E6 Btu/hr 4300 Design Wet Bulb, 74 F
Cooling Water Seawater

Range, F	16	16	16	16
Approach, F	8	10	12	14
CW Flow, gpm	554,100	554,100	554,100	554,100
Marley Model No.	8294 -6.0-16	8262 -6.0-16	8242 -6.0-16	8242 -6.0-12
Number of Towers	2	2	2	2
Diameter, ft	260	234	219	219
Height, ft	67	64	61	60
Pumping Head, ft	43	40	37	36
No. Fans/Fan BHP	16/193	16/193	16/192	12/193
L/G Ratio	1.367	1.592	1.824	2.066
Evaporation Loss, %	1.5	1.5	1.5	1.5
Price, $ million	26.55	21.51	19.01	18.8
Range, F	20	20	20	20
Approach, F	8	10	12	14
CW Flow, gpm	443,200	443,200	443,200	443,200
Marley Model No.	8263 -6.0-16	8233 -6.0-16	8214 -6.0-16	8216 -6.0-12
Number of Towers	2	2	2	2
Diameter, ft	235	212	197	199
Height, ft	66	62	59	59
Pumping Head, ft	41	38	36	35
No. Fans/Fan BHP	16/192	16/192	16/192	16/192
L/G Ratio	1.247	1.46	1.669	1.887
Evaporation Loss, %	1.9	1.8	1.8	1.8
Price, $ million	21.9	17.65	15.916	15.49
Range, F	24	24	24	24
Approach, F	10	12	14	16
CW Flow, gpm	369,400	369,400	369,400	369,400
Marley Model No.	8233 -6.0-16	8209 -6.0-16	8210 -6.0-12	8194 -6.0-12
Number of Towers	2	2	2	2
Diameter, ft	212	193	194	181
Height, ft	63	60	59	57
Pumping Head, ft	39	36	35	34
No. Fans/Fan BHP	16/192	16/192	12/192	12/192
L/G Ratio	1.174	1.373	1.569	1.768
Evaporation Loss, %	2.1	2.2	2.1	2.1
Price, $ million	17.65	15.41	14.78	13.3

Reference 6a: Marley Cooling Tower Company, S. Assman (MCT) to F. Kuo (ESI) on 5/5/92 - Natural Draft and Round Mechanical Draft CT Parametric Technical and Cost Information For Comparative Study

EXHIBIT 24

Cooling System Material and Installation Unit Costs

1. Major Site Development

		Units	Material	Installation
a.	NDCT	$1000	12,600	5,900
b.	RMDCT	$1000	12,800	6,200

Includes capital cost for general clearing and grading, maintenance roads, lighting, cathodic protection, condenser tube cleaning system, valving facilities, power wiring to pumps, instrumentation wiring and controls, and water treatment facilities (e.g. make-up water clarification and blowdown sludge removal).

2. Circulating Water Pump Intake Structure

		Units	Material	Installation
a.	NDCT	$/cu ft	7.72	20.25
b.	RMDCT	$/cu ft	7.72	20.25

3. Reinforced Concrete Pipe

		Units	Material	Installation
a.	Pipe Dia: 72"	$/ft	206	403
b.	84"	$/ft	276	459
c.	132"	$/ft	458	696
d.	144"	$/ft	521	733
e.	150"	$/ft	553	752

4. CW Pump Installation — 10% of material cost

5. CW Pump Motor Installation Cost — 4% of material cost

6. Cooling Tower Basin Excavation Grading & Backfilling

		Units	Material	Installation
a.	NDCT	$/cu ft	5.95	36.54
b.	RMDCT	$/cu ft	7.79	44.21

7. Unit Auxiliary Transformer

		Units	
a.	Material	$/MVA	12,619
b.	Installation	$/MVA	2,260

EXHIBIT 24
Cooling System Material and Installation Unit Costs

8. Power Cable

		Material ($/MVA/ft)	Installation ($/MVA/ft)
a.	HV Cable to Intake Switchgear	*	*
b.	Cable from Intake Swgr to a CWP	*	*
c.	Cable from Power Center to a Fan	140	234.7

* Included in major site development

9. Control Wiring

		Units	Material	Installation
a.	Circ Water Pump	$/pump/ft	*	*
b.	MDCT Fan	$/fan/ft	2.25	10

* Included in major site development

10. Instrumentation & Control

		Units	Material	Installation
a.	CW Pumps	$/pump	9,400	4,600
b.	CT Fans	$/fan	2,600	1,900

11. CWP Switchgear

Included in major site development.

12. Fan Power Center

		Units	
a.	Material	$/Cntr	291,000
b.	Installation	$/Cntr	19,000

Nine fans per power center. Includes transformer, breaker and required switchgear.

EXHIBIT 25
NDCT Investment, Comparable Annual and Capitalized Costs

Cooling Water Approach F	Condenser Tube Water Velocity ft/sec	Investment Cost $1E6	Annual Cost w/Adjustment $1000	Capitalized Cost $1E6
12	5.00	95.29	34230	146.16
	5.20	96.49	33921	144.84
	5.40	97.44	33694	143.87
	5.60	98.72	33622	143.56
	5.80	99.56	33493	143.01
	6.00	103.33	34173	145.91
	6.20	105.27	34439	147.05
	6.40	107.08	34721	148.25
	6.60	109.30	35146	150.07
	6.80	110.92	35515	151.64
	7.00	113.06	36082	154.06
	7.20	115.72	36810	157.17
14	5.00	89.10	34435	147.03
	5.20	91.69	34486	147.25
	5.40	93.66	34443	147.07
	5.60	95.89	34536	147.46
	5.80	97.62	34608	147.77
	6.00	101.83	35400	151.15
	6.20	104.01	35721	152.52
	6.40	106.04	36057	153.96
	6.60	108.46	36533	155.99
	6.80	110.86	37047	158.19
	7.00	112.93	37515	160.18
	7.20	115.41	38124	162.78
16	5.80	91.58	35100	149.87
	5.60	90.06	35164	150.15
	5.40	88.46	35269	150.59
	5.20	86.44	35351	150.94
	5.00	84.84	35618	152.08
	6.00	95.23	35642	152.19
	6.20	98.47	36117	154.21
	6.40	101.68	36647	156.48
	6.60	104.22	37066	158.27
	6.80	107.10	37654	160.78
	7.00	109.37	38125	162.79
	7.20	113.31	39060	166.78

Note: 1995 dollars;for computer printout see Appendix B Sheets 1-3.

EXHIBIT 28
NDCT ECONOMIC EVALUATION CURVE

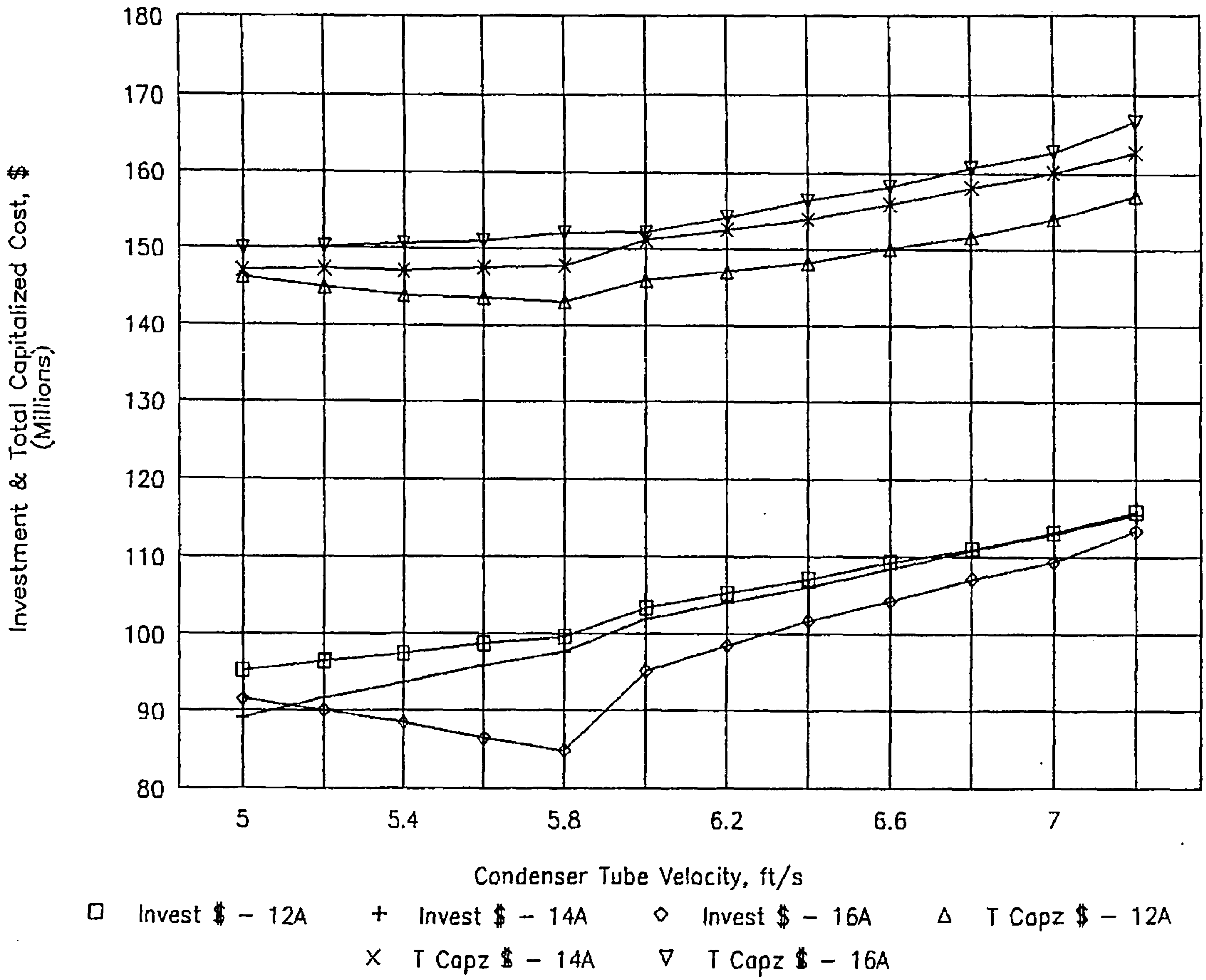


EXHIBIT 27

RMDCT Investment, Comparable Annual and Capitalized Costs

Cooling Water Approach F	Condenser Tube Water Velocity ft/sec	Investment Cost $1E6	Annual Cost w/Adjustment $1000	Capitalized Cost $1E6
8	5.00	94.26	33735	144.04
	5.20	96.49	33921	144.84
	5.40	98.60	34279	146.37
	5.60	100.94	34753	148.39
	5.80	103.00	35189	150.25
	6.00	106.13	35994	153.69
	6.20	108.25	36571	156.15
	6.40	110.38	37184	158.77
	6.60	111.84	37654	160.78
	6.80	113.56	38227	163.22
	7.00	115.07	38774	165.56
	7.20	118.04	39735	169.66
10	5.00	88.51	33876	144.65
	5.20	90.23	33879	144.66
	5.40	91.37	33797	144.31
	5.60	92.83	33870	144.62
	5.80	94.54	34063	145.44
	6.00	97.27	34692	148.13
	6.20	98.63	35011	149.49
	6.40	100.41	35472	151.46
	6.60	102.22	35980	153.63
	6.80	103.73	36470	155.72
	7.00	104.83	36894	157.53
	7.20	107.80	37841	161.58
12	5.00	85.64	34373	146.77
	5.20	86.95	34334	146.60
	5.40	87.86	34296	146.44
	5.60	89.24	34440	147.05
	5.80	90.49	34602	147.75
	6.00	93.28	35141	150.05
	6.20	94.42	35258	150.55
	6.40	95.99	35538	151.74
	6.60	97.62	35879	153.20
	6.80	98.59	36179	154.48
	7.00	99.88	36590	156.23
	7.20	101.62	37154	158.64

Note: 1995 dollars;for computer printout see Appendix B Sheets 4-6.

EXHIBIT 28
RMDCT ECONOMIC EVALUATION CURVE

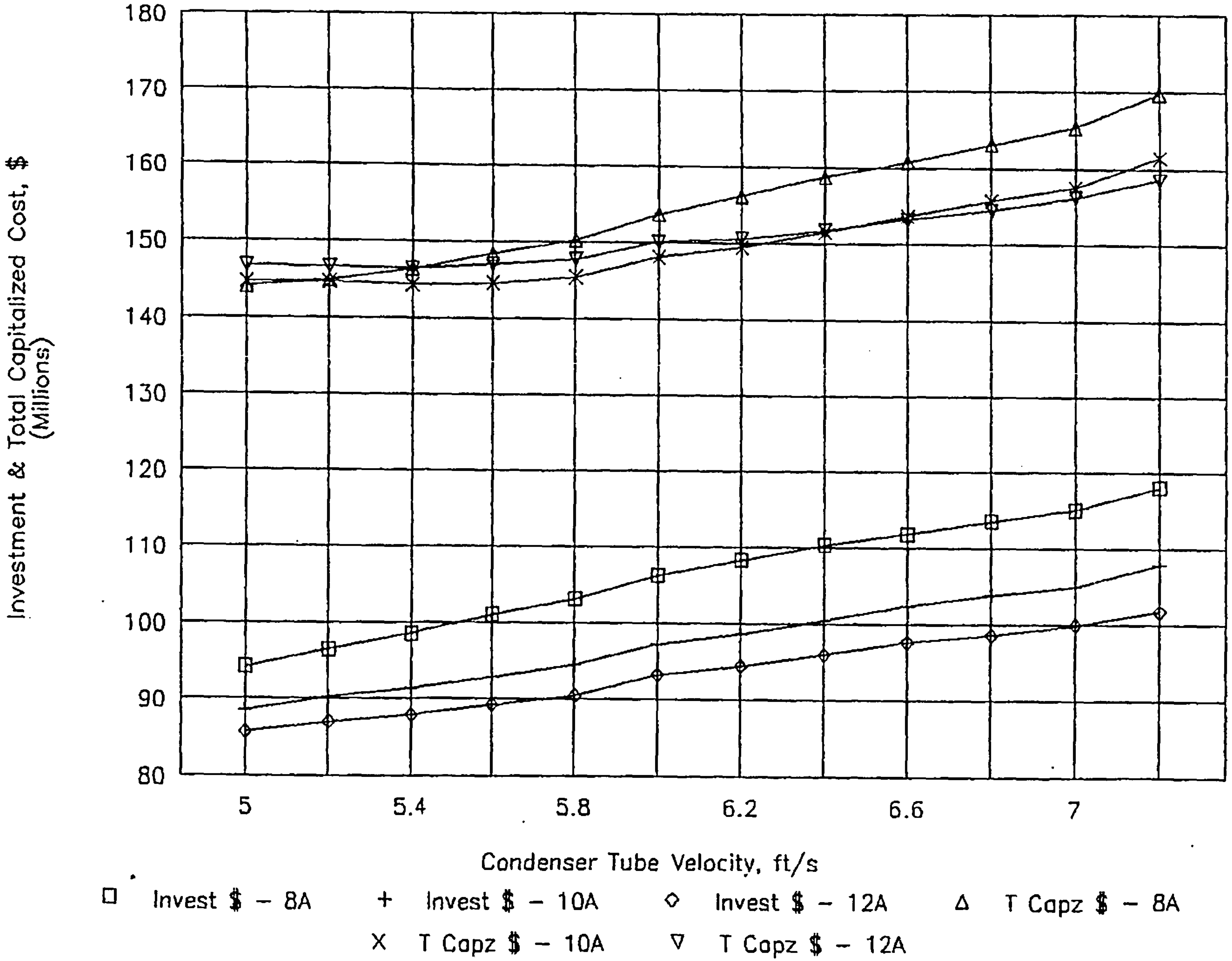


EXHIBIT 29
Condensing System Computer Printout - NDCT

SPECIFICATIONS FOR CASE NO. 1 NATURAL DRAFT COOLING TOWER -HAGLEY RNOTE — MNE DEPT A J MUSTO 06/10/92 PAGE 7

CW INLET DESIGN TEMPERATURE (F)	86.00	PERFORMANCE AT DESIGN CONDITIONS:		NO. OF COOLING TOWERS-CT	1
CONDENSER TEMPERATURE RISE (F)	20.23	TG CAPABILITY (MW)	605.79	NO. OF CELLS PER CT	0
TUBE DIAMETER (INCHES)/GAUGE	0.875/22	AVG CONDENSER PRESSURE (IN.HGA)	3.18	CT DESIGN APPROACH TEMP (F)	12.00
TOTAL TUBE LENGTH (FT/SHELL)	42.30			TOTAL CT FAN MOTOR INPUT KW	0
NO. OF TUBES PER SHELL/SHELLS	14562/3			TOTAL CW-PUMP MOTOR INPUT KW	7479
NO. OF TUBE PASSES/PRESS ZONES	1/1	PERFORMANCE AT MAX SUMMER TEMP		CW PUMP MOTOR RATING (HP)	2500
TOTAL SURFACE AREA (SQ FT)	423000	TG CAPABILITY (MW)	605.79	CW SYSTEM TDH (FT)	74.50
CIRCULATING WATER FLOW (GPM)	416200	AVG CONDENSER PRESSURE (IN.HGA)	3.18	CW MAIN CONDUIT DIAM (FT)	12.00
TUBE VEL. AT ABOVE CW FLOW (FPS)	5.80			NO. OF CW PUMPS	4
		AVG SEASONAL COND PRESS (IN.HGA)	1.84 2.59 2.79	TG CAPABIL. @ WB 30.8F (MW)	0.0

E S T I M A T E D   I N I T I A L   I N V E S T M E N T   C O S T

ACCOUNT CODE	INITIAL INVESTMENT COST ITEMS	TODAY'S MATERIAL COST UNIT	TODAY'S MATERIAL COST TOTAL 1000$	TODAY'S INSTALLATION COST UNIT	TODAY'S INSTALLATION COST TOTAL 1000$	ESCALATION 1000$ MATERIAL	ESCALATION 1000$ INSTALLATION
	MAJOR SITE DEVELOPMENT	------------	12606	------------	5900	1616	756
1.11	LOCAL IMPROVEMENT TO SITE-CLEARING	------------		C$/ACRE	0		0
2.1	LOCAL GRADING	------------		0.00$/CU YD	0		0
2.5	PILING	0.00$/SQ FT	0	0.00$/SQ FT	0	0	0
3.42	INTAKE STRUCTURE	7.72$/CU FT	666	20.25$/CU FT	1747	85	226
3.2	CIRCULATING WATER CONDUIT: MAIN	0$/LIN FT	0	0.00$/LIN FT	0	0	0
3.2	BRANCHES	339.75$/LIN FT	1481	482.99$/LIN FT	2105	190	270
3.32	DISCHARGE STRUCTURE	0.00$/CU FT	0	0.00$/CU FT	0	0	0
3.41	COOLING TOWER BASIN	5.95$/SQ FT	840	36.54$/SQ FT	5282	110	477
3.44	COOLING TOWER SUPERSTRUCTURE	10192540$/EACH	10193	12457349$/EACH	12458	1304	1596
5.1	TG BUILDING (DIFFERENTIAL)	0$/FT HT	0	0$/FT HT	0	0	0
4.10	TG PEDESTAL (DIFFERENTIAL)	0$/FT HT	0	C$/FT HT	0	0	0
7.1	TG & ACCESSORIES (DIFFERENTIAL)	0.00$/KVA	0	0.00$/KVA	0	0	0
10.211	CONDENSER SHELL	0$/EACH	0	0$/EACH	0	0	0
10.213	CONDENSER TUBE (TITAN)	0.0000$/FT	0	0.0000$/FT	0	0	0
10.221	CIRCULATING WATER PUMP	572342$/EACH	2289	108743$/EACH	435	293	56
15.3	CIRCULATING WATER PUMP MOTOR	360743$/EACH	1443	28850$/EACH	115	185	15
14.1	INSTRUMENTATION & CONTROL	9400.00$/EACH	38	4600.00$/EACH	18	5	2
15.11	START-UP & STANDBY TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.12	UNIT AUXILIARY TRANSFORMER (DIFFERENTIAL)	12619$/MVA	187	2260$/MVA	19	14	2
15.21	CIRCULATING WATER SWITCHGEAR	0$/PUMP	0	0$/PUMP	0	0	0
15.6	WIRING FOR CIRCULATING WATER SYSTEM	0$/MVA	0	0$/MVA	0	0	0
15.1	UNIT MAIN POWER TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.23	FAN MOTOR POWER CENTER + REQ'D SWGR & FEEDER	0$/CENTER	0	C$/CENTER	0	0	0
	TOTAL		29676		28079	3802	3597

TOTAL DIRECT ESCALATED COST: MATERIAL PLUS 5.00% SALES/USE TAX PLUS INSTALLATION	66829
INDIRECT CONSTRUCTION COST INCLUDING PROFESSIONAL SERVICES	10167
CONTINGENCY (14.00% OF DIRECT PLUS INDIRECT COST)	10779
UTILITY'S EXPENSES, INTEREST DURING CONSTRUCTION, & LAND	10778
TOTAL ESTIMATED INVESTMENT COST 1000$	98553

E S T I M A T E D   C O M P A R A B L E   I N V E S T M E N T   &   A N N U A L   C O S T S

				1000$/YR	MILLS/KWH
UNIT NET CAPABIL. W/S//S/P (MW)	609.0 602.4 589.1 580.7	CW SYSTEM FUEL COST (BASE VALUE)		0	
DIFFERENTIAL UNIT NET CAPABILITY (MW)	9.02	ANNUAL FIXED CHARGES (AT RATE 0.23421)		23081	
		WATER COST (AT 19.$/MILLION GALLONS + CHEMICALS)		331	
UNIT NET ANNUAL GENERATION (MWH/YR)	3929137	MAINTENANCE (2.00% OF TOTAL INV + 0$/FAN)		1971	
DIFFERENTIAL UNIT NET GENERATION (MWH/YR)	160312	SUBTOTAL ANNUAL COST		25383	
		NET PRODUCTION COST			6.444
WATER CONSUMPTION (MILLION GALLONS/YR)	4774				
		ADJUSTMENT FOR DIFFERENTIAL CAPABILITY		0	
TOTAL ANNUAL UNIT FUEL COST (AT 0.0000$/MILLION BTU) (1000$)	0	ADJUSTMENT FOR DIFFERENTIAL NET ANNUAL GENERATION		7795	
		TOTAL COMPARABLE ANNUAL COST INCLUDING ADJUSTMENTS FOR EQUALIZED CAPABILITY & NET ANNUAL GENERATION		33178	
TOTAL COMPARABLE INVESTMENT COST INCLUDING CAPABILITY ADJUSTMENT (1000$)	98553	COMPARABLE NET PRODUCTION COST INCL. ADJUSTMENTS			8.214

EXHIBIT 30
Condensing System Computer Printout - RMDCT

SPECIFICATIONS FOR CASE NO. 1 MECH. DRAFT COOLING TOWER -MARLEY QUOTE — AMI DEPT A J MUSTO 04/10/92 PAGE 7

CW INLET DESIGN TEMPERATURE (F)	84.00	PERFORMANCE AT DESIGN CONDITIONS:		NO. OF COOLING TOWERS-CT	2
CONDENSER TEMPERATURE RISE (F)	22.36	TG CAPABILITY (MW)	404.51	NO. OF CELLS PER CT	12
TUBE DIAMETER (INCHES)/GAUGE	0.875/22	AVG CONDENSER PRESSURE (IN.HGA)	3.24	CT DESIGN APPROACH TEMP (F)	10.00
TOTAL TUBE LENGTH (FT/SHELL)	42.50			TOTAL CT FAN MOTOR INPUT KW	3979
NO. OF: TUBES PER SHELL/SHELLS	14562/3			TOTAL CW PUMP MOTOR INPUT KW	6318
NO. OF: TUBE PASSES/PRESS ZONES	1/1	PERFORMANCE AT MAX SUMMER TEMP		CW PUMP MOTOR RATING (HP)	2000
TOTAL SURFACE AREA (SQ FT)	423000	TG CAPABILITY (MW)	400.46	CW SYSTEM TDH (FT)	68.45
CIRCULATING WATER FLOW (GPM)	373100	AVG CONDENSER PRESSURE (IN.HGA)	3.41	CW MAIN CONDUIT DIAM (FT)	11.00
TUBE VEL. AT ABOVE CW FLOW (FPS)	5.20			NO. OF CW PUMPS	4
		AVG SEASONAL COND PRESS (IN.HGA)	1.79 2.17 2.81	TG CAPABIL. @ HG 30.8F (MW)	0.0

E S T I M A T E D   I N I T I A L   I N V E S T M E N T   C O S T

ACCOUNT CODE	INITIAL INVESTMENT COST ITEMS	TODAY'S MATERIAL COST UNIT	TODAY'S MATERIAL COST TOTAL 1000$	TODAY'S INSTALLATION COST UNIT	TODAY'S INSTALLATION COST TOTAL 1000$	ESCALATION 1000$ MATERIAL	ESCALATION 1000$ INSTALLATION
	MAJOR SITE DEVELOPMENT		12800		4200	1640	794
1.11	LOCAL IMPROVEMENT TO SITE-CLEARING			0$/ACRE	0		0
2.1	LOCAL GRADING			0.00$/CU YD	0		0
2.5	PILING	0.00$/SQ FT	0	0.00$/SQ FT	0	0	0
3.42	INTAKE STRUCTURE	7.72$/CU FT	617	20.25$/CU FT	1618	79	207
3.2	CIRCULATING WATER CONDUIT: MAIN	0$/LIN FT	0	0.00$/LIN FT	0	0	0
3.2	BRANCHES	307.89$/LIN FT	1414	471.65$/LIN FT	2167	181	278
3.32	DISCHARGE STRUCTURE	0.00$/CU FT	0	0.00$/CU FT	0	0	0
3.41	COOLING TOWER BASIN	7.79$/SQ FT	625	44.21$/SQ FT	3547	80	454
3.44	COOLING TOWER SUPERSTRUCTURE	391723.0$/EACH	7835	478773.$/EACH	9574	1004	1227
5.1	TG BUILDING (DIFFERENTIAL)	0$/FT HT	0	0$/FT HT	0	0	0
4.18	TG PEDESTAL (DIFFERENTIAL)	0$/FT HT	0	0$/FT HT	0	0	0
7.1	TG & ACCESSORIES (DIFFERENTIAL)	0.00$/KVA	0	0.00$/KVA	0	0	0
10.211	CONDENSER SHELL	0$/EACH	0	0$/EACH	0	0	0
10.213	CONDENSER TUBE (TITAN)	0.0000$/FT	0	0.0000$/FT	0	0	0
10.221	CIRCULATING WATER PUMP	530238$/EACH	2121	100749$/EACH	403	272	52
15.3	CIRCULATING WATER PUMP MOTOR	279169$/EACH	1117	22333$/EACH	89	143	11
14.1	INSTRUMENTATION & CONTROL	3571.43$/EACH	100	2285.71$/EACH	64	13	8
15.11	START-UP & STANDBY TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.12	UNIT AUXILIARY TRANSFORMER (DIFFERENTIAL)	12619$/MVA	144	2260$/MVA	24	18	3
15.21	CIRCULATING WATER SWITCHGEAR	0$/PUMP	0	0$/PUMP	0	0	0
15.6	WIRING FOR CIRCULATING WATER SYSTEM	58819$/MVA	673	111471$/MVA	1278	86	164
15.1	UNIT MAIN POWER TRANSFORMER (DIFFERENTIAL)	0$/MVA	0	0$/MVA	0	0	0
15.23	FAN MOTOR POWER CENTER + ASS'D SWGR & FEEDER	291000$/CENTER	873	19000$/CENTER	57	112	7
	TOTAL		28319		23024	3628	3206

TOTAL DIRECT ESCALATED COST: MATERIAL PLUS 5.00% SALES/USE TAX PLUS INSTALLATION	61773
INDIRECT CONSTRUCTION COST INCLUDING PROFESSIONAL SERVICES	9283
CONTINGENCY (14.00% OF DIRECT PLUS INDIRECT COST)	9948
UTILITY'S EXPENSES, INTEREST DURING CONSTRUCTION, & LAND	10100
TOTAL ESTIMATED INVESTMENT COST 1000$	91104

E S T I M A T E D   C O M P A R A B L E   I N V E S T M E N T   &   A N N U A L   C O S T S

					1000$/YR	MILLS/KWH
UNIT NET CAPABIL. W/ST/S/P (MW)	407.0 400.2 386.0	372.9		CW SYSTEM FUEL COST (BASE VALUE)	0	
DIFFERENTIAL UNIT NET CAPABILITY	(MW)	34.83		ANNUAL FIXED CHARGES (AT RATE 9.23%)	21337	
				WATER COST (AT 19.8/MILLION GALLONS + CHEMICALS)	316	
UNIT NET ANNUAL GENERATION	(MWH/YR)	3923212		MAINTENANCE (3.00% OF TOTAL INV + 3747$/FAN)	2824	
DIFFERENTIAL UNIT NET GENERATION	(MWH/YR)	134217		SUBTOTAL ANNUAL COST	24476	
				NET PRODUCTION COST		6.239
WATER CONSUMPTION	(MILLION GALLONS/YR)	4547				
				ADJUSTMENT FOR DIFFERENTIAL CAPABILITY	0	
TOTAL ANNUAL UNIT FUEL COST				ADJUSTMENT FOR DIFFERENTIAL NET ANNUAL GENERATION	9031	
(AT 0.0000$/MILLION BTU)	(1000$)	0		TOTAL COMPARABLE ANNUAL COST INCLUDING ADJUSTMENTS		
TOTAL COMPARABLE INVESTMENT COST				FOR EQUALIZED CAPABILITY & NET ANNUAL GENERATION	33507	
INCLUDING CAPABILITY ADJUSTMENT	(1000$)	91104		COMPARABLE NET PRODUCTION COST INCL. ADJUSTMENTS		8.293

EXHIBIT 31
RMDCT and NDCT Component Material and Installation Differential Costs

	RMDCT Material 1000$	RMDCT Installation 1000$	NDCT Material 1000$	NDCT Installation 1000$
Major Site Development	12800	6200	12600	5900
Intake Structure	617	1618	666	1747
Circulating Water Conduit	1414	2167	1481	2105
Cooling Tower Basin	625	3547	860	5282
Cooling Tower Superstructure	7835	9576	10193	12458
Circulating Water Pump	2121	403	2289	435
Circulating Water Pump Motor	1117	89	1483	115
Instrumentation and Control	100	64	38	18
Unit Auxiliary Transformer	144	26	107	19
Wiring for Circulating Water System	673	1278	0	0
Fan Motor Power Center & Required Switchgear and Feeder	873	57	0	0

LIST OF APPENDICES

APPENDIX A

Computer Program for Cooling Water System Sizing and Economic Evaluation

APPENDIX A

COMPUTER PROGRAM FOR COOLING WATER SYSTEM SIZING AND ECONOMIC EVALUATION

A. INTRODUCTION

The input data to the computerized optimization program for the selection of a steam condensing system based on costs is comprised of the equipment design variables, the heat rates, layout information, and system loads as well as equipment, material and labor pricing information. The program, utilizing these inputs together with mathematical, theoretical and design assumptions, selects and develops cooling system features and components including concrete or earth structures (such as intake structures or cooling tower basins), circulating water main and branch conduits, circulating water pumps and motors (and condenser shells and tubes, if necessary). The cost impact of the differential unit transformers' (main, auxiliary and startup) size, which depends on the cooling water system power requirements, is also considered.

B. COMPUTER PROGRAM

The program selects, analyzes and prices all the system components as follows:

(1) The size of the circulating water pumps, motors and condensers (if necessary) is determined from design formulas and the costs calculated based on the latest pricing lists available assuming reasonable discounts.

(2) The intake structure size is calculated from general design relationships and priced volumetrically ($/cu ft of structure).

(3) Cooling tower data is calculated as a function of approach to the wet bulb temperature and the cooling range based on the input data.

(4) The optimum size of the circulating water conduits is selected based on a cost analysis of fixed and annual charges (investment and fuel cost)

(5) The auxiliary power demand and annual energy consumption for the cooling water system are determined from the units loading schedule, circulating water pump and cooling tower fan design and mode of operation data.

(6) Makeup water consumption and water treatment chemical cost is calculated as a function of evaporation rate, drift losses and cycles of concentration in the circulating water circuit.

For each case the economic analysis includes the determination of initial investment cost and annual system cost (fixed charges on the investment cost plus the annual operating and maintenance costs). These costs include items related to condenser cooling systems only and do not represent total plant costs.

1. Investment Costs

The total investment cost consists of estimated major site development cost associated with each alternative cooling system plus computerized variable costs. The major site development cost, included in the overall computerized optimization program for each of the alternative cooling systems, is estimated based on information shown on plot plans and the specific quantities required for the following:

Clearing - general area,
Grading - general area,
Makeup, blowdown system and water treatment -
equipment, piping, structures,
Maintenance roads,
Condenser tube cleaning system, and
Cathodic protection and lighting.

For the cooling pond and spray canal systems, the total civil work cost was included in major site development cost.

Computerized variable investment costs are developed by the computer to make up the remaining investment cost items which are added to the major site development cost for the total direct cost of material and installation.

Included in the computerized variable costs are:

Local improvement to site-clearing,
Local grading,
Circulating water intake structure,
Spray cooling modules,
Circulating water pumps and motors,
Circulating water main and branch water conduits,

Cooling tower basin and superstructure,
Condenser shells and condenser tubes (if necessary),
Instrumentation and control for circulating water pumps,
Unit main power transformer (differential),
Unit auxiliary transformer (differential),
Start-up and stand-by transformer (differential),
Circulating water system switchgear, and
Wiring for circulating water system.

The size and cost of turbine generator equipment, pedestal and building for an existing plant is assumed fixed for all cases considered.

2. Comparable Annual Costs

The estimated "Comparable Annual Costs" is developed using the computerized program and the results are recorded in the following manner:

Description of Cooling System	Comment
Type of Cooling System	- A controlled variable identifying the specific type of Cooling Water System.
Maximum Cooling Water Temperature	- Cooling water temperature entering condenser at maximum meteorological conditions is used for unit capability calculation at adverse conditions.
Degrees of Approach at Design Conditions	- A controlled variable within the typical range of values for the type of cooling water system.
Plant Net Capability at Maximum Meteorological, Design and Average Seasonal Conditions	
(1) Turbine Generator	- Energy generated operating at condenser pressure coincident with the appropriate meteorological conditions.

Description of Cooling System	Comment
(2) Estimated Plant Auxiliary Power Excluding Cooling Water System, kW	- A set of constant values for each of the various loads common to all cooling water system alternatives studied.
(3) CW System Auxiliary Power, kW	- Calculation and Summation of circulating water pump motor and cooling tower fan motor or of spray module motor input power.
(4) Plant Net Capability at Various Conditions, kW	- These calculation values reflect the restraint or limit in plant capability at various conditions. The value at average seasonal conditions is the basis for monetary evaluation of differential net capability.
Plant Net Annual Generation kWh/yr	- Integrate (Net Plant Capacity x Period Hours) for three (3) periods per year and three (3) values of turbine generator loads.
Differential Plant Net Capability, kW	- Base value is the maximum dependable plant net output of 620 MW. Any value smaller is penalized for this loss of capabilit- As instructed by JCP&L, larger values were not credited.
Differential Plant Net Generation, kWh/yr	- Base value is a preselected specified value. Any value smaller is penalized for this loss of kilowatt hours generation. A value larger is credited on the same basis.

Description of Cooling System	Comment
	Plant Net Generation with the existing cooling system was used as base value.
Annual Fixed Charges, $/yr	- The total Estimated Investment Cost has been defined. This cost multiplied by an Annual Fixed Charge Rate is equal to the Annual Fixed Charges.
Annual Plant and Cooling Water System Fuel Costs, $/yr	- It is assumed that the Nuclear Reactor annual fuel consumption and hence the thermal output is the same for all alternative cooling water systems. The total plant annual fuel cost is calculated based on the integral of three (3) periods per year, the percent loading regimen per period, the thermal rating of the nuclear reactor and a specified fuel cost. This cost is the same for all alternatives. A variable is the fuel cost related to the cooling water system. This cost is calculated based on circulating water pump motor and cooling tower fan motor energy requirements (kWh/yr) and is included in the comparable annual system costs.

Description of Cooling System	Comment
Water Consumption	- Evaporation plus Drift Loss plus blowdown equals makeup.
Water Costs, \$/yr	- Makeup x Unit Cost of water treatment.
Maintenance, \$/yr	- A Calculated Cost as a percentage of Investment Cost. For mechanical draft towers, a maintenance charge per fan is added.
Subtotal Annual Cost, \$/yr	- A summation of above costs.
Net Unit Production Cost, mills/kWh	- This cost is based on the above annual costs divided by net annual generation.
Adjustment for Differential Plant Net Capability, \$/yr	- This differential capability cost is calculated at a rate of incremental net capability levelized cost times the levelized Fixed Annual Charge Rate times the differential net capability (see next comment).
Adjustment for Differential Plant Net Annual Generation, \$/yr	- This differential generation cost adjustment is calculated assuming a fixed levelized charge per kWh times the differential plant net annual generation.
Total Comparable Annual Cost Including Adjustment for Equalized Capability and Generation, \$/yr	- A Summation of Subtotal Annual Cost and Adjustment.
Comparable Net Unit Production Cost, mills/kWh	- This cost is based on Total Comparable Annual Cost Including Adjustments for Equalized Capability and Generation divided by base net generation.

The above computation is repeated for each condensing system using various values for the water velocity in condenser tubes and cooling tower approach (the latter is defined as the difference between the circulating water temperature entering the condenser and the ambient wet bulb temperature). Then all the cooling system costs are sorted and results printed in ascending order of annual cost with capability and generation adjustments, the least costly being first on the list.

APPENDIX B

Cooling System Alternatives - Computer Printout Summary Data

Sheet 1	NDCT - 12 F Approach
Sheet 2	NDCT - 14 F Approach
Sheet 3	NDCT - 16 F Approach
Sheet 4	RMDCT - 8 F Approach
Sheet 5	RMDCT - 10 F Approach
Sheet 6	RMDCT - 12 F Approach

Natural Draft Cooling Tower, 12F Approach Temperature

SORT IN ASCENDING ORDER OF ANNUAL COST INCLUDING CAPABILITY & GENERATION ADJUSTMENTS

ND 12A

	ANNUAL SYSTEM COSTS		INVESTMENT COSTS		PERFORMANCE AT DESIGN CONDITIONS		SURFACE	CONDENSER	AND	CONDENSER		TUBES	PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP	
CASE NO.	WITHOUT ADJUSTMNTS	INCLUDES ADJUSTMNTS	INITIAL + ESCAL	TOTAL	TG CAPABIL. (MW)	AVG BACK PRESS IN HG	TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	UNIT NET CAPABIL. (MW)	AVG BACK PRESS IN HG
1	25675	33493	67516	99560	605.79	3.18	423000	20.2	416.2	5.80	43	0.875	580.26	3.18
2	25462	33622	66941	98719	604.22	3.25	423000	21.0	401.8	5.60	43	0.875	579.14	3.25
3	25138	33694	66050	97436	602.53	3.33	423000	21.7	387.5	5.40	43	0.875	577.88	3.33
4	24897	33921	65400	96485	600.66	3.41	423000	22.6	373.1	5.20	43	0.875	576.43	3.41
5	26632	34173	70163	103325	607.23	3.11	423000	19.6	430.5	6.00	43	0.875	581.20	3.11
6	24596	34230	64579	95293	598.63	3.51	423000	23.5	358.8	5.00	43	0.875	574.80	3.51
7	27125	34439	71498	105268	608.57	3.05	423000	18.9	444.9	6.20	43	0.875	582.03	3.05
8	27587	34721	72747	107084	609.79	3.00	423000	18.3	459.2	6.40	43	0.875	582.72	3.00
9	28151	35146	74288	109302	610.92	2.94	423000	17.8	473.6	6.60	43	0.875	583.27	2.94
10	28562	35515	75401	110921	611.95	2.89	423000	17.3	487.9	6.80	43	0.875	583.73	2.89
11	29106	36082	76886	113059	612.93	2.85	423000	16.8	502.3	7.00	43	0.875	584.10	2.85
12	29783	36810	78752	115723	613.84	2.80	423000	16.3	516.6	7.20	43	0.875	584.37	2.80

Natural Draft Cooling Tower, 14F Approach Temperature

SORT IN ASCENDING ORDER OF ANNUAL COST INCLUDING CAPABILITY & GENERATION ADJUSTMENTS

MNE DEPT A J MUSTO 06/02/92

ND 14A

CASE NO	ANNUAL SYSTEM COSTS: WITHOUT ADJUSTMNTS	ANNUAL SYSTEM COSTS: INCLUDES ADJUSTMNTS	INVESTMENT COSTS: INITIAL + ESCAL	INVESTMENT COSTS: TOTAL	PERFORMANCE AT DESIGN CONDITIONS: TG CAPABIL. (MW)	PERFORMANCE AT DESIGN CONDITIONS: AVG BACK PRESS IN HG	SURFACE CONDENSER AND CONDENSER TUBES: TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP: UNIT NET CAPABIL. (MW)	PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP: AVG BACK PRESS IN HG
1	23017	34435	60344	89100	594.70	3.70	423000	23.5	358.8	5.00	43	0.875	575.04	3.51
2	24175	34443	63469	93656	598.58	3.51	423000	21.7	387.5	5.40	43	0.875	578.01	3.33
3	23676	34486	62129	91692	596.72	3.60	423000	22.6	373.1	5.20	43	0.875	576.61	3.41
4	24742	34536	65004	95885	600.34	3.43	423000	21.0	401.8	5.60	43	0.875	579.22	3.25
5	25183	34608	66189	97622	601.98	3.35	423000	20.2	416.2	5.80	43	0.875	580.28	3.18
6	26254	35400	69140	101833	603.48	3.29	423000	19.6	430.5	6.00	43	0.875	581.18	3.11
7	26806	35721	70634	104005	604.88	3.22	423000	18.9	444.9	6.20	43	0.875	581.97	3.05
8	27322	36057	72029	106035	606.16	3.16	423000	18.3	459.2	6.40	43	0.875	582.62	3.00
9	27937	36533	73710	108456	607.37	3.11	423000	17.8	473.6	6.60	43	0.875	583.14	2.94
10	28548	37047	75377	110857	608.48	3.06	423000	17.3	487.9	6.80	43	0.875	583.56	2.89
11	29075	37515	76815	112933	609.54	3.01	423000	16.8	502.3	7.00	43	0.875	583.89	2.85
12	29706	38126	78544	115414	610.49	2.96	423000	16.3	516.6	7.20	43	0.875	584.13	2.80

Natural Draft Cooling Tower, 16F Approach Temperature

SORT IN ASCENDING ORDER OF ANNUAL COST INCLUDING CAPABILITY & GENERATION ADJUSTMENTS

PNE DEPT A J MUSTO C6/02/92

ND 16A

	ANNUAL SYSTEM COSTS		INVESTMENT COSTS		PERFORMANCE AT DESIGN CONDITIONS		SURFACE CONDENSER AND CONDENSER TUBES						PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP	
CASE NO	WITHOUT ADJUSTMNTS	INCLUDES ADJUSTMNTS	INITIAL + ESCAL	TOTAL	TG CAPABIL. (MW)	AVG BACK PRESS IN HG	TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	UNIT NET CAPABIL. (MW)	AVG BACK PRESS IN HG
1	23651	35100	62065	91580	598.02	3.54	423000	20.2	416.2	5.80	43	0.875	580.68	3.18
2	23264	35164	61021	90061	596.39	3.62	423000	21.0	401.8	5.60	43	0.875	579.57	3.25
3	22854	35269	59917	88455	594.63	3.70	423000	21.7	387.5	5.40	43	0.875	578.32	3.33
4	22340	35351	58522	86439	592.68	3.79	423000	22.6	373.1	5.20	43	0.875	576.87	3.41
5	21933	35618	57430	84861	590.57	3.90	423000	23.5	358.8	5.00	43	0.875	575.24	3.51
6	24579	35642	64607	95231	599.55	3.47	423000	19.6	430.5	6.00	43	0.875	581.64	3.11
7	25403	36117	66847	98471	601.01	3.40	423000	18.9	444.9	6.20	43	0.875	582.47	3.05
8	26219	36647	69068	101680	602.35	3.34	423000	18.3	459.2	6.40	43	0.875	583.18	3.00
9	26865	37066	70817	104224	603.61	3.28	423000	17.8	473.6	6.60	43	0.875	583.75	2.94
10	27597	37654	72811	107101	604.78	3.23	423000	17.3	487.9	6.80	43	0.875	584.22	2.89
11	28174	38125	74373	109372	605.88	3.18	423000	16.8	502.3	7.00	43	0.875	584.60	2.85
12	29175	39060	77131	113311	606.90	3.13	423000	16.3	516.6	7.20	43	0.875	584.89	2.80

Round Mechanical Draft Cooling Tower, 8F Approach Temperature

SORT IN ASCENDING ORDER OF ANNUAL COST INCLUDING CAPABILITY & GENERATION ADJUSTMENTS

MD 8A

	ANNUAL SYSTEM COSTS		INVESTMENT COSTS		PERFORMANCE AT DESIGN CONDITIONS		SURFACE CONDENSER AND CONDENSER TUBES						PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP	
CASE NO	WITHOUT ADJUSTMNTS	INCLUDES ADJUSTMNTS	INITIAL + ESCAL	TOTAL	TG CAPABIL. (MW)	AVG BACK PRESS IN HG	TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	UNIT NET CAPABIL. (MW)	AVG BACK PRESS IN HG
1	25372	33735	63958	94258	606.30	3.16	423000	23.5	358.8	5.00	43	0.875	569.57	3.51
2	25968	33921	65494	96492	608.17	3.07	423000	22.6	373.1	5.20	43	0.875	571.09	3.41
3	26529	34279	66941	98598	609.88	2.99	423000	21.7	387.5	5.40	43	0.875	572.43	3.33
4	27152	34753	68561	100940	611.39	2.92	423000	20.9	401.8	5.60	43	0.875	573.58	3.25
5	27702	35189	69986	103002	612.79	2.85	423000	20.2	416.2	5.80	43	0.875	574.57	3.18
6	28527	35994	72167	106127	614.07	2.79	423000	19.6	430.5	6.00	43	0.875	575.41	3.11
7	29087	36571	73638	108252	615.26	2.74	423000	18.9	444.9	6.20	43	0.875	576.12	3.05
8	29646	37184	75109	110376	616.35	2.69	423000	18.3	459.2	6.40	43	0.875	576.69	3.00
9	30030	37654	76107	111835	617.38	2.64	423000	17.8	473.6	6.60	43	0.875	577.13	2.94
10	30485	38227	77300	113560	618.33	2.59	423000	17.3	487.9	6.80	43	0.875	577.46	2.89
11	30883	38774	78341	115073	619.22	2.55	423000	16.8	502.3	7.00	43	0.875	577.69	2.85
12	31666	39735	80424	118040	620.05	2.51	423000	16.3	516.6	7.20	43	0.875	577.83	2.80

Round Mechanical Draft Cooling Tower, 10F Approach Temperature

SORT IN ASCENDING ORDER OF ANNUAL COST INCLUDING CAPABILITY & GENERATION ADJUSTMENTS

MNE DEPT A J MUSTO 06/04/92

MD 10A

	ANNUAL SYSTEM COSTS		INVESTMENT COSTS		PERFORMANCE AT DESIGN CONDITIONS		SURFACE CONDENSER AND CONDENSER TUBES						PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP	
CASE NO	WITHOUT ADJUSTMNTS	INCLUDES ADJUSTMNTS	INITIAL + ESCAL	TOTAL	TG CAPABIL. (MW)	AVG BACK PRESS IN HG	TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	UNIT NET CAPABIL. (MW)	AVG BACK PRESS IN HG
1	24623	33797	61990	91372	606.30	3.16	423000	21.7	387.5	5.40	43	0.875	572.73	3.33
2	25007	33870	63004	92834	607.92	3.08	423000	21.0	401.8	5.60	43	0.875	573.88	3.25
3	23871	33876	60015	88505	602.56	3.33	423000	23.5	358.8	5.00	43	0.875	569.84	3.51
4	24324	33879	61209	90228	604.51	3.24	423000	22.6	373.1	5.20	43	0.875	571.37	3.41
5	25457	34063	64196	94544	609.42	3.01	423000	20.2	416.2	5.80	43	0.875	574.89	3.18
6	26176	34692	66101	97267	610.77	2.95	423000	19.6	430.5	6.00	43	0.875	575.73	3.11
7	26538	35011	67036	98632	612.01	2.89	423000	18.9	444.9	6.20	43	0.875	576.45	3.05
8	27009	35472	68268	100407	613.15	2.84	423000	18.3	459.2	6.40	43	0.875	577.04	3.00
9	27490	35980	69528	102224	614.23	2.79	423000	17.8	473.6	6.60	43	0.875	577.49	2.94
10	27839	36470	70570	103728	615.22	2.74	423000	17.3	487.9	6.80	43	0.875	577.83	2.89
11	28181	36894	71325	104831	616.16	2.70	423000	16.8	502.3	7.00	43	0.875	578.07	2.85
12	28966	37841	73414	107798	617.02	2.65	423000	16.3	516.6	7.20	43	0.875	578.22	2.80

Round Mechanical Draft Cooling Tower, 12F Approach Temperature

MD 12A

	ANNUAL SYSTEM COSTS		INVESTMENT COSTS		PERFORMANCE AT DESIGN CONDITIONS		SURFACE CONDENSER AND CONDENSER TUBES						PERFORMANCE AT PEAK LOAD CONDITION WATER TEMP	
CASE NO	WITHOUT ADJUSTMNTS	INCLUDES ADJUSTMNTS	INITIAL + ESCAL	TOTAL	TG CAPABIL. (MW)	AVG BACK PRESS IN HG	TOTAL SURFACE AREA (SQ FT)	TEMP RISE ACROSS COND	TOTAL FLOW 1000 GPM	TUBE VELOC (FPS)	TUBE LGTH (FT)	TUBE DIAM (IN)	UNIT NET CAPABIL. (MW)	AVG BACK PRESS IN HG
1	23681	34296	59574	87860	602.53	3.33	423000	21.7	387.5	5.40	43	0.875	573.43	3.33
2	23430	34334	58944	86945	600.66	3.41	423000	22.6	373.1	5.20	43	0.875	572.32	3.41
3	23084	34373	58036	85644	598.63	3.51	423000	23.5	358.8	5.00	43	0.875	571.05	3.51
4	24054	34440	60537	89235	604.22	3.25	423000	21.0	401.8	5.60	43	0.875	574.37	3.25
5	24394	34602	61415	90490	605.79	3.18	423000	20.2	416.2	5.80	43	0.875	575.17	3.18
6	25131	35141	63373	93275	607.23	3.11	423000	19.6	430.5	6.00	43	0.875	575.96	3.11
7	25435	35258	64158	94422	608.57	3.05	423000	18.9	444.9	6.20	43	0.875	576.71	3.05
8	25851	35538	65250	95994	609.79	3.00	423000	18.3	459.2	6.40	43	0.875	577.32	3.00
9	26281	35879	66379	97618	610.92	2.94	423000	17.8	473.6	6.60	43	0.875	577.79	2.94
10	26539	36179	67044	98591	611.95	2.89	423000	17.3	487.9	6.80	43	0.875	578.16	2.89
11	26879	36590	67935	99876	612.93	2.85	423000	16.8	502.3	7.00	43	0.875	578.43	2.85
12	27339	37154	69151	101617	613.84	2.80	423000	16.3	516.6	7.20	43	0.875	578.60	2.80